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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1910.

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SUMMARY OF PROGRESS

OF THE

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AND

MUSEUM

FOR 1910.

I.—*INTRODUCTION.*

By J. J. H. Teall, M.A., Sc.D., F.R.S., Director.

In England and Wales the primary six-inch Survey has been carried on for several years in the mining districts of Cornwall and Devon, South Wales, and the counties of Nottinghamshire and Derbyshire. The work in each of these three districts was brought to a conclusion in 1909, and in 1910 the three surveying parties, or field-units, were accordingly transferred to new areas. Two field-units are still engaged in Carboniferous districts with a view to completing the six-inch Survey of the coalfields as soon as possible, while the third is employed in the London and South-eastern District where the want of six-inch maps has long been felt.

During the past year work has been done in the following counties:—Denbighshire, Flintshire, Warwickshire, Staffordshire, Berkshire, Buckinghamshire, and Surrey.

In Denbighshire the Carboniferous rocks of the southern part of the Vale of Clwyd have been surveyed and progress has been made with the mapping of the coalfield about Wrexham. Advantage is being taken of the survey of the Denbighshire Coalfield to bring the old six-inch maps of the adjacent Flintshire Coalfield up to date.

In Warwickshire and South Staffordshire surveying has been carried on in the coalfields and in the intervening ground occupied by Triassic Rocks.

In Berkshire and Buckinghamshire the work has been taken up on the eastern margin of the area already surveyed on the six-inch scale and carried eastwards with the object of completing the survey on that scale of the London area and the south-east of England.

In Scotland the work has proceeded on the same lines as in former years. The original survey has been continued in Mull and South Morvern, and in the counties of Sutherland, Perth, and Inverness. The revision of the Carboniferous areas has been continued on the margins of the great central coalfield of Lanarkshire and Renfrewshire; in the neighbourhood of East Kilbride on the west, Carluke on the south, and Shotts and Fauldhouse on

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the east. Progress has also been made with the revision of the detached basin of Douglas. An important change in the method of publishing the Scottish one-inch geological maps has been made during the year. Hitherto these maps have only been obtainable in the expensive hand-coloured form. Colour printing has now been introduced and four maps have been published; a special map of Arran and three of the ordinary one-inch sheets relating to the Edinburgh District (Sheet 32), East Lothian and Haddingtonshire (Sheet 33), and a portion of Skye and Glenelg (Sheet 71).

Pre-Cambrian Rocks and Crystalline Schists.

Crystalline schists with associated igneous rocks of various ages have been surveyed in Mull and South Morvern, in the eastern portion of Sutherland, and in parts of Perthshire and Inverness-shire lying to the east and north of the Moor of Rannoch.

In Mull no point of special interest, so far as the schists are concerned, has been brought to light, but further evidence of minor intrusions of earlier date than the granite of the Ross of Mull has been obtained. An intrusive sheet of foliated lamprophyre which occurs on the west side of Ardalanish Bay has been invaded and metamorphosed by the granite. Lamprophyre dykes have already been proved to cut the granite, so that in this part of the island intrusions of this type of rock have taken place at two distinct epochs.

In East Sutherland rocks of both the Lewisian and the Moine types have been mapped, although the relations of the one to the other have not been definitely established. It was observed that where the gneisses of Lewisian type are traversed by shear zones they simulate the Moine schists, and that where the latter have been modified by intrusions of granite they assume more or less the characters of the former.

The work which has been carried on in Invernesshire on the west side of Loch Treig has resulted in the recognition of three of the rock groups already mapped in the Ballachulish District, and the tectonic relations of the three groups suggest the presence of an extensive "slide" cutting out at one point the middle member of the sequence.

Lower Palæozoic Rocks.

No field work has been done in Lower Palæozoic areas, but certain igneous rock collected in former years have been examined. The volcanic rocks of Skomer Island, Pembrokeshire, somewhat doubtfully referred to the Arenig period, have furnished an interesting series ranging in composition from soda-felsites to basalts. The terms skomerite and marloesite have been proposed for two intermediate types.

Devonian.

Outliers of Old Red Sandstone consisting in part of breccias and conglomerates with subangular fragments of granite, schist, and quartzite have been mapped in the Kildonan District of Sutherlandshire.

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In England the work on rocks from Devonian areas has been entirely of a petrographical character. The granite of Bodmin Moor and the rocks of the contact-aureole, so far as they are developed in the Padstow and Camelford sheet, have been described and also certain pillow-lavas, diabases, and albite-proterobases (minverites) occurring in the same sheet. The igneous rocks of the Newton Abbot District consisting of albite-spilites, quartz-keratophyres, diabases, minverites, and picrite have also been examined.

Carboniferous Rocks.

The work of the Survey in Denbighshire has resulted in the introduction of greater detail than was possible when the original survey on the one-inch scale was carried out. The Carboniferous Limestone has been separated into three groups on lithological grounds, and important beds of sandstone in the Coal Measures have been separately mapped, thus bringing out points of structure that are not shown on the earlier map. The productive Coal Measures in this area are conformably succeeded by red barren measures which were classed as Permian at the time of the original survey. The determination of the thickness of these measures is a matter of great importance in connexion with the development of the concealed portion of the coalfield.

Coal Measures have also been mapped in North Warwickshire. The fault which bounds the coalfield on its north-western side has been traced and an area of the upper red barren measures, which overlie the grey measures with workable coals as in the South Staffordshire field, has been surveyed.

In Scotland revision work has been continued in the Shotts and Fauldhouse District and in the eastern and south-eastern portions of the great central coalfield of Lanarkshire. The extensive workings which have been carried on since the original survey was completed have enabled additions and corrections to be made. In view of the fact that a considerable time must necessarily elapse before the new map with its accompanying memoir can be published, the results are given in greater detail than would otherwise be necessary.

The revision of the East Kilbride basin has now been completed. It has resulted in a considerable increase in our knowledge of the lower part of the Carboniferous Limestone Series and the upper part of the Calciferous Sandstone Series, and a definite correlation of the strata in this district with those of the typical Hurlet District has now been established. The discovery of a "Pendleside fauna" in the Calciferous Sandstone of this area was referred to last year. The fossils have now been determined and the lists are published in the palæontological section of this Summary.

In the Carluke District areas of Calciferous Sandstone, Carboniferous Limestone, and Coal Measures have been revised. Work has also been carried on in the Douglas basin where evidence of a marked thinning of the strata from east to west has been obtained. Representatives of Upper Old Red Sandstone and of the Calciferous Sandstone occur in the area surveyed, but

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the dividing line has not yet been fixed. It does not appear to be marked by any abrupt change in lithological character.

The small patch of Carboniferous rocks in Morvern, originally discovered more than thirty years ago by Professor Judd, has been examined during the year and found to be more extensive than has hitherto been supposed. They contain thin lenticular coaly streaks and yield plants which have been determined by Dr. Kidston who points out that, although they do not belong to well marked zonal forms, the assemblage indicates that the rocks are approximately of the same age as the productive Coal Measures of Central Scotland.

Permian.

One of the important problems awaiting solution in the Midlands is the relation of the so-called Permian rocks to the Coal Measures on the one hand and the Trias on the other. Following the practice adopted in the map and memoir on the North Staffordshire Coalfield the strata conformably overlying the productive Coal Measures in Denbighshire, South Staffordshire, and Warwickshire, in which red colours often predominate, are no longer regarded as Permian. That this change of classification will have an important effect on the appearance of the map is certain, but it is not yet certain that the Permian colour will entirely disappear from the map. In the neighbourhood of Hints, a village about four miles south-west of Tamworth, occur certain red beds containing a peculiar limestone conglomerate. So far as recent observations have gone their age cannot be determined. They are indicated as Permian on the old series map, but they may belong to the Bunter.

Triassic Rocks.

In the Denbighshire districts in which work has been carried on the Triassic rocks are for the most part concealed by drift, but small exposures have been met with in the Vale of Clwyd and in the Dee valley east of Wrexham. In the areas surveyed in Staffordshire and Warwickshire they are, however, well exposed and considerable tracts of both Bunter and Keuper have been mapped about Cannock Chase, Rugely, Tamworth, and Lichfield. Certain faults which affect both Carboniferous and Triassic rocks are known to have a much greater throw in the former than in the latter, and to be due therefore to movement along the same planes at two distinct epochs.

Jurassic Rocks.

In Morvern (N.W. Argyllshire) certain fossiliferous rocks between the Trias and the Lias have been doubtfully referred to the Rhætic period. Further observations of the Lower Lias of this district have confirmed the conclusions arrived at by Professor Judd many years ago. A small area of Jurassic rocks has also been surveyed in Mull, and some observations have been made on the present state of the workings in the coals of Lower Oolite age at Brora in East Sutherland.

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Cretaceous Rocks.

Areas of chalk have been surveyed in Buckinghamshire and Berkshire.

In the Summary of Progress for 1908 attention was directed to a most unexpected discovery of Cretaceous fossils in a sandstone quarry in Caithness, but no opinion was expressed as to whether the sandstone was a transported boulder or in place. This question has now been settled by boring. The sandstone has been proved to form part of a transported mass. An account of the boring operations will be found in Appendix III.

Small areas of Cretaceous rocks have been mapped in the Carsaig District of Mull and on the shores of Loch Aline in South Morvern.

Tertiary Rocks.

Certain Eocene tracts have been surveyed in the London and South-eastern district, but the work has not as yet proceeded far enough to yield results of general interest.

In Scotland further progress has been made with the mapping of the Tertiary igneous rocks of the Island of Mull. In view of the fact that one of the officers who had been engaged in surveying the highly complex area forming the central mountain group has recently been transferred to the Geological Survey of Ireland, a somewhat detailed account of his latest results is given in the following pages. Some observations on the Tertiary coals of the island have been made. They prove that these coals are sporadic in their mode of occurrence and of little economic value.

Pleistocene and Recent.

The survey of the superficial deposits which is carried on *pari passu* with that of the underlying rocks has yielded several interesting results. In Staffordshire and Warwickshire it has been found possible to divide the Glacial deposits into two groups: one derived from the west and the other from the east. The mapping of the drifts in the Vale of Clwyd and in the Wrexham District has thrown considerable light on the history of Denbighshire in Glacial and Post-glacial times. Evidence of the existence of another deep channel of drift in the eastern counties has been furnished by a boring near Saham Toney in Norfolk. Perhaps the most interesting result obtained in Scotland has been the definite proof, already referred to, that the sandstone of Leavad in Caithness containing Neocomian fossils is part of a large transported mass.

II.—FIELD WORK.

(A.) ENGLAND AND WALES.

The geological surveying of the three districts on which the field-staff has been concentrated for some years having been completed so far as is contemplated at present, work was commenced in 1910 in three new districts, as follows:—

1. Denbighshire District under Mr. G. W. Lamplugh.
2. Warwickshire District under Mr. G. Barrow.
3. London and S.E. District under Mr. C. Reid.

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In all three the work has been so laid out as to continue the six-inch mapping done in previous years through areas not yet surveyed on that scale, with at the same time some revision of the previous six-inch work where through the progress of mining or for other reasons the maps required bringing up to date, as in the Flintshire Coalfield.

In addition to the ordinary field-work various borings have been examined in different parts of the country, and among them several borings for coal in the concealed extension of the Yorkshire-Nottingham Coalfield.

1.—Denbighshire District.

G. W. Lamplugh, F.R.S., District Geologist.
H. H. Thomas, M.A., B.Sc
D. A. MacAlister, A.R.S.M.
B. Smith, M.A.
L. J. Wills, M.A.
} Geologists.

The field-work of the year consisted in the survey on the six-inch scale of part of the Carboniferous and newer rocks in the One-inch Sheet 121, Wrexham, which includes the greater portion of the Denbighshire Coalfield. A revision of the Flintshire Coalfield area in Sheets 108 and 96 was commenced.

Vale of Clwyd.—In the western part of Sheet 121, Mr. B. Smith completed the survey of the post-Silurian rocks of the Vale of Clwyd. The area in the Sheet to the north (No. 108) was mapped some years ago by Dr. A. Strahan, and the work has now been continued southward to the end of the Carboniferous trough. Some small tracts of Silurian rocks were mapped by Mr. Smith in this district in order to complete certain six-inch maps. They presented no features requiring special comment.

Carboniferous Basement Beds.—On the eastern side of the Clwydian trough the Carboniferous rocks are faulted down against Silurian strata; but on the western side, the unconformable base of the Carboniferous formation emerges, though the outcrop is usually obscured by drift. The red basement beds seen in the area to the north, near Ruthin (Sheet 108) are probably continuous southward along the margin of the Carboniferous trough to the neighbourhood of Llanelidan, though they are rarely visible and are likely to be irregular in thickness. The best exposure observed by Mr. Smith lies ¼ mile SE. of Nant Clwyd Hall, where a small pit revealed 8 to 12 feet of red, purple and green shales and marls, with bands of sandstone, calcareous sandstone and fine-grained limestone. The full thickness of the series near this spot may be 20 to 30 feet. The southern edge of the Carboniferous trough is determined by faults, so that the base of the formation is not seen, but traces of the red basement beds were recognised again at the margin of the main outcrop of the Carboniferous rocks in the Llandegla District, three miles farther east, where, however, the series is evidently patchy and discontinuous.

Carboniferous Limestones.—The upward sequence of limestones recognised by Mr. Smith in the Vale of Clwyd is: (1) The brown limestones, about 320 feet thick, well exposed on the

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western side of the Vale; also traceable in the Llandegla District, though not so readily separable there from the next division. (2) The white limestones, over 200 feet thick, which are sometimes dolomitic where disturbances have affected them. These limestones occupy the space between the main branches of the boundary fault at the south end of the Vale. In the Llandegla District they include, near their base, some dark limestones. (3) The grey limestones with calcareous sandstones, which have a thickness of not less than 1,100 feet. Only the lower part of this division remains on the western side of the Vale of Clwyd, but the whole of it is present at the southern end, where a cherty band occurring 160 to 180 feet above its base affords a useful clue to the complicated stratigraphy. It also includes a belt of coralline limestone which can be traced in many places; and in the Llandegla District it contains, near its base, some dark shales and limestones approximating in type to the black limestones mapped by Dr. Strahan in the district to the north (Sheet 108). The intercalations of sandstone appear at two horizons; the lower occurring about 500 feet below the top of the division, is composed almost entirely of loosely cemented quartz sand. It averages some 20 feet in thickness, and is fairly persistent. The higher is much more irregular and is split up by layers of limestone and calcareous sandstone. The highest beds of the division, seen immediately below the Millstone Grit east of Llandegla, consist of dark cement-stones and rotten-stones with shaly layers containing *Fenestella;* these rest on massive crinoidal limestone with nodules of chert.

The upper portion of the Carboniferous Limestone series was also mapped farther eastward by Mr. H. H. Thomas in the high ground south and west of Minera on the border of the coalfield. It is well exposed here in a bold fault-scarp which reveals an alternation of dark crinoidal limestones, sandy limestones, shales, and pebbly calcareous grits. The highest beds are extremely sandy, but have cores of compact limestone. They are succeeded by the pebbly grits and quartzites of the Millstone Grit. The highest decalcified sandstone in the Limestone series has been worked at the northern end of Minera Mountain for polishing and scouring material.

Millstone Grit.—The Millstone Grit is not seen at the southern end of the Vale of Clwyd, but further eastward it covers a wide stretch of country mapped by Mr. Smith between Llandegla and Nant y Ffrith. Mr. Smith describes the lower beds as consisting of white pebbly sandstone, occasionally incoherent, with coarser and in places very pebbly grits above. Bands of dark shale, cherty grit and chert are intercalated with the higher grits, these cherty beds being sometimes fossiliferous and including layers of fine grained limestone. At higher horizons where the chert is absent the grits contain plant remains.

Mr. Thomas who mapped the continuation of the Millstone Grit in the Minera District noted a similar sequence and found that nearly all the lower portion has undergone secondary silicification. He observed the presence of plant-bearing shales in the series at Bwlch Gwyn, and of dark mudstones with marine fossils

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among the debris from several old mine shafts. The upper portion was formerly quarried extensively for building at Berwig, and the silicified cherty beds are dug on a large scale for road-metal at Bwlch Gwyn.

Coal Measures.—In the Vale of Clwyd some purple sandstones, shown by the previous work in the country further north (Sheet 108) to belong to the Coal Measures, were included in the area mapped by Mr. Smith. Their only clear exposure was in a stream-section south of Ty'n Llanfair where they were revealed to a depth of a few feet, between exposures of Carboniferous Limestone and of Triassic Sandstone, but their contact with neither formation was visible. The sandstone near Llanfair Chapel, shown on the old map as belonging to the Coal Measures, proves to be one of the sandstones in the Carboniferous Limestone Series.

In the productive Coal Measures of the Brymbo and Coed Poeth District, Mr. H. H. Thomas traced the succession upward from the top of the Millstone Grit to the chief sandstone of the Coal Measures which occurs about 550 feet above the Main Coal.

Most of the workable coal-seams are grouped within the 200 feet of strata above the Main Coal, but in a few instances there are workings in seams below this coal. The sandstone referred to affords great aid to the mapping, as it makes a conspicuous outcrop at Brymbo, Moss, and Coed Poeth. It is a soft, yellow ferruginous rock of medium grain, strongly false-bedded, and having an average thickness (including shale partings) of about 150 feet; it has been largely quarried for building-stone all over the district.

To the eastward of the high ridges formed by this sandstone in the area surveyed by Mr. Lamplugh, the ground sinks rapidly to the level of the drift-plain which extends thence up to and beyond the river Dee. The solid rocks of this tract are almost entirely hidden under thick glacial deposits, a few isolated exposures along the valley of the Alyn being all that is seen of the Coal Measures above the sandstone in the country north of Wrexham. The geology of this part of the map must therefore depend mainly upon information to be obtained from mining operations. It is known that the unproductive Upper Coal Measures are brought against the productive Middle Coal Measures east of Gwersyllt Park by a big fault (the Wrexham Fault) running NNW.—SSE., with an easterly downthrow, so that the strata exposed along the Alyn between Bradley Mills and Gresford Bridge, in the area surveyed by Mr. Wills, belong to the Upper Measures though their precise position in the series has not yet been ascertained. Mr. Wills has traced in this district a succession of red, grey and green shales with red and grey sandstones, occasionally somewhat conglomeratic, which appears to have a thickness of about 480 feet, but neither top nor bottom of the series is visible.

South of the Alyn valley for several miles there are no further rock-exposures till we reach the valley of the Clywedog at Kings Mills, a mile S.E. of Wrexham. Here, in ground surveyed by Mr. Wills, the stream has cut a gorge in red sandstones and red

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marls (the latter worked as a terra-cotta clay) which were formerly considered to be of Permian age but are now classed with the Upper Coal Measures. Owing to the isolated character of the exposure there is little direct evidence for the relationship of these rocks, but their position is certainly high in the series. Similar rocks are revealed three miles further southward, on their line of strike, in a gully near Park Eyton, in ground surveyed by Mr. MacAlister, within a mile of the next exposures, in the valley of the Dee.

Below Overton Bridge the Dee has its valley for many miles entirely in the Glacial drifts, but above this bridge it flows more usually in a deep ravine excavated partly in the solid rocks. Most of its tributaries also in this quarter have trenched down to the solid floor in their lower reaches. In the ground surveyed by Mr. MacAlister, between Pen-y-lan Bridge and Overton Bridge the rocks consist of red and purple sandstones, frequently calcareous and more or less conglomeratic, with thick intercalations of bright red marls. These beds, like those farther north, agree in direction of dip and strike with the productive Coal Measures and are now believed to represent the uppermost part of the barren Upper Coal Measures, having their equivalent in the Keele Series of North Staffordshire. Their thickness is rendered uncertain by the probability of concealed faulting; an estimate made by Mr. MacAlister for a portion of the series almost continuously exposed transverse to the strike amounts to nearly 2,000 feet, but may be exaggerated if there is repetition of the beds.

In the gorge of the Dee above Pen-y-lan Bridge, surveyed by Mr. Wills, lower members of the Upper Coal Measures are exposed, including the Coed-yr-Allt Series of grey calcareous sandstones and thin coals, and the underlying purple and variegated marls which we may distinguish as the "Ruabon Marls." In this neighbourhood, however, the succession is greatly complicated by faulting, and Mr. Wills found that the sequence could be traced more clearly in the ground to the south, bordering the valley of the Ceiriog River. There he estimated that the Ruabon Marls have their base about 800 to 850 feet above the Main Coal, and are themselves about 850 feet thick, including in their lower part some bands of greenish felspathic grit, sandstone and breccia (resembling the Espley Rock of North Staffordshire) and in their upper part some thin limestones with entomostraca and *Spirorbis*. The overlying Coed-yr-Allt Series has been measured to a thickness of 160 feet, but there may be a further portion above this, hidden by drift. Its chief member is a grey calcareous sandstone (the "Coed-yr-Allt rock") about 60 feet thick, with black and grey shales and thin coals above and below.

The classification of these Upper Coal Measures was first attempted many years ago by D. C. Davies;* and their correlation with the North Staffordshire sequence was pointed out at a later date by Dr. W. Gibson.†

* *Quart. Journ. Geol. Soc.*, vol. 33, 1877, p. 10.
† *Quart. Journ. Geol. Soc.*, vol. 57, 1901, p. 253.

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Trias.—The southern termination of the Triassic rocks in the Vale of Clwyd has been mapped by Mr. Smith, but the area is so thickly overspread with drift that exposures are rare. A few sections were seen, however, all in false-bedded red sand or sandrock of the Lower Mottled Sandstone type.

In the Wrexham District, although the Trias no doubt underlies the ground along the eastern margin of Sheet 121, it is everywhere buried deeply under drift, and not a single exposure was found. But in carrying the work up to the Dee, in Sheet 122, Mr. Wills mapped a small area of Triassic sandstone at Holt, where the river has encountered a partly buried ridge of this formation. The sandstones are pebbly in parts, have a steep easterly dip, and are broken by numerous small faults.

Faults.—Besides the system of NNW. faults which traverse the Flintshire and Denbighshire Coalfields and to which the great Vale of Clwyd Fault belongs, two belts of dislocation distinct from it in direction and character, have played a leading part in determining the structure of North Wales. Of these the complex Bala Fault, running from ENE. to WSW., is the most important, while a sheaf of fractures which we propose to call the Viaduct Faults, and which range more nearly east-and-west, constitute the second of the belts referred to. One other series of faults deserve mention. These are the metalliferous veins which run in a NW. to SE. direction; to this series, as judged by their direction, belong the Minera lead-veins.

The Bala fault was mapped by Mr. Smith from the southern end of the Vale of Clwyd to Bylch Gwyn and by Mr. Thomas in its prolongation north-eastward into Nant-y-Ffrith. Near Llandegla this fault splits into two main branches, the northerly branch, to be distinguished as the Llanelidan Fault, striking west of Llanelidan; and the other, the Bala Fault proper, continuing in a south-westerly direction into the Silurian country. In the angle between them, the rocks are cut up by a plexus of minor faults, and Mr. Smith found that considerable alteration of the Old Series map was required in this neighbourhood. Eastward, between Llandegla and Nant-y-Ffrith the fault usually resolves itself into sheaf of parallel or curving fractures which enclose lenticular slices of the displaced formations between them. The lenticles not infrequently consist of long narrow ridges of a younger formation dropped in between older rocks. Slices of Carboniferous Limestone, for example, have been wedged in between Ordovician and Silurian.

The Viaduct Faults were studied by Mr. Wills in the river gorge west of Pen-y-lan; their course is approximately E.—W., and they introduce many complications of structure in the Carboniferous rocks, which cannot be resolved until the ground farther westward has been surveyed.

In the portion of the coalfield mapped by Mr. Thomas the principal faults were found to have a NNW.—SSE. course, but with many cross-fractures striking roughly E.—W., so that the strata are cut up into great blocks. All the faults observed are normal, and the stretching implied by these dislocations amounts in the Brymbo district to 200 yards in a mile from east

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to west. The Minera Fault which at Minera consists of a series or gashes carrying galena and zinc-blende ranges ESE. or SE. and has been traced for several miles.

Glacial.—The abundant drift that cumbers the southern end of the Vale of Clwyd was found by Mr. Smith to have come principally from the west or somewhat south of west. Boulders from the Arenig district, frequently of large size, are scattered everywhere, the Boulder Clay chiefly composed of Silurian detritus spreads eastward on to the Carboniferous Limestone on the west side of the vale. Farther east, on the lower Triassic ground, the Boulder Clay is red and sandy, and this material has been carried eastward on to the Silurian rocks which bound the vale. The Boulder Clay is occasionally heaped up in drumlins, and tracts of moundy drift composed of sand and gravel occur near Pwll-glas and Eyarth Hall.

The drift of the Carboniferous dip-slopes bordering the plain west of Wrexham, in the tracts mapped by Mr. Thomas and Mr. Lamplugh, is of two kinds. On the higher ground it is principally a sandy yellowish rubbly clay derived in great part from the Carboniferous rocks. Toward the foot of the slopes, this material gives place irregularly to red clay, with fewer stones, but among them, granites and other boulders foreign to the district. On the slope of Minera Mountain, however, at 1,200 feet above O.D. the highest drift is a reddish sandy Boulder Clay associated with patches of gravel, both containing granites and other stones of northern derivation. Along the margin of the drift-plain there are great spreads of coarse bouldery gravel and sand, sometimes rising into mounds but more often comparatively flat, which appear to be the old flood-deltas of big streams descending from the upland. Gravels of this kind also surround the mouths of two remarkable gorges in the Carboniferous rocks at Moss and at Plas Power. These gorges, each a little over a mile in length, and 100—200 feet deep, are cut straightly and sharply through the main sandstone of the Coal Measures in the direction of its strike, *i.e.*, NNW.—SSE., and they end blindly and abruptly northward in a notch on the very crest of the deep Cegidog Valley. Their flat wet floors at present carry no drainage except the meagre seepage from their slopes. They appear to be excellent examples of overflow channels excavated by flood-waters from the melting ice-sheets at the close of the Glacial period.

Another interesting result of fluvio-glacial conditions is the perfect example of an esker which occurs in association with the glacial gravels immediately south of Gwersyllt Park. This esker takes the form of a sharply curved ridge of coarse gravel about ½ mile long, 40 to 60 feet high, and often not more than 50 yards broad at the base. It is flanked on both sides by swampy hollows without natural drainage.

The drifts of the low country north and east of Wrexham were mapped by Mr. Wills who reports that the district is separable into two areas which differ in physical features as well as in the composition of the glacial deposits. These are (1) the Boulder Clay Plain, extending westward from the Dee, a low smooth tract

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composed of reddish calcareous clay often obscurely laminated and containing very few stones; and (2) the Sand and Gravel Plateau, stretching from Gresford to and beyond Wrexham. The plateau terminates suddenly eastward in a steep brow, apparently an original feature of the sand and gravel, which overlooks the plain of Boulder Clay.

The surface of the plateau is diversified by moundy ground and by pit-like depressions or kettle-holes, as well as by long winding dry valleys. One of these valleys, near Llay Villa, ends as a hanging valley, with its mouth 50 feet above the alluvial flat of the River Alyn, thus affording an indication of the amount of erosion effected by that river since any stream flowed in the dry valley. The sands and gravels are about 130 feet thick near Marford, but they thin gradually southward to about 80 feet at Llan-y-pwll and to still less at Marchwiel. South of the Clywedog Valley they appear to pass under an almost stoneless red clay, and patches or lenses of Boulder Clay are also interbedded with them in the country north of Wrexham. A few crumbs of marine shells and a stone pierced by a boring mollusc were observed in the gravels. In many places the sands pass downward into well-stratified water-logged silts, which rest on Boulder Clay. These silts give much trouble in sinking colliery shafts and, since they also produce a characteristic soil, an attempt was made to map them out separately; but owing to their intricate relationship with the Boulder Clay this was found to be possible only in a few places. At Holt a peculiar loamy drift of the brick-earth type was mapped; it affords a soil which has given rise to the extensive strawberry culture of the district.

The drift-covered country south-east of Wrexham, extending beyond the Dee to Overton, was surveyed by Mr. MacAlister who found that the sands and gravels of this district occur mainly between beds of Boulder Clay, though they sometimes rise through the Boulder Clay in mounds. In this area, therefore, an upper Boulder Clay covers most of the uneroded surface at all altitudes, and the sand and gravel emerge chiefly along the valleys, particularly along that of the Dee. The upper Boulder Clay is a reddish-brown calcareous clay, often loamy, and not infrequently showing traces of lamination. It contains few stones, and is thus distinguished from the lower Boulder Clay in which boulders are frequently numerous; the stones of both clays include granites and other rocks which are not of Welsh origin, and these boulders, together with a few small fragments of marine shells found in the deposit, indicate that the Boulder Clays of this district are the product of ice which has moved southward from the Irish Sea basin. The best exposure of the upper Boulder Clay is in a river-cliff of the Dee at Dorlan Gôch, between Overton and Bangor, which shows about 50 feet of nearly stoneless clay, apparently abutting against soft yellow sand and loam.

Mr. Wills mapped a similar sequence of drifts in the country south of the Dee and east of Chirk, again finding two Boulder Clays of somewhat different composition, with foreign boulders and a few shell-fragments, often separated by lenticles of soft sand and loam which appeared to set in at slightly different

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horizons at different places. West of the ridge of Middle Coal Measures at Black Park, however, the drift seems to be of another type and fills a deep preglacial valley which is crossed by the present Dee.

Late-glacial and Post-glacial.—Since the drifts were deposited, all the rivers of the districts have re-excavated their valleys, and in many places have adopted new courses by cutting channels across the buried ridges of solid rock. The Dee affords a striking example of this procedure at Holt and in the reaches above Overton Bridge. During the excavation of its new gorges it has left a succession of terraces, frequently overspread by flood-gravels, to mark the stages of erosion from late-glacial times to the present.

These terraces are especially well-developed between the Ceiriog confluence and Bangor-is-y-coed. Here the majority are found by Mr. MacAlister and Mr. Wills to fall into the following classification:—

Oldest Terraces, probably fluvio-glacial; obscure.
60-ft. Terrace.
40-ft. Terrace.
20-ft. Terrace.
Present Alluvium.

The 60-ft. terrace is well-developed north of Overton Bridge in the ground surveyed by Mr. MacAlister and has been traced without a break for 3½ miles. Usually, however, the terraces are continuous only for short distances, owing to the inroads made upon them by the swinging of the river.

2.—Warwickshire District.

Mr. G. Barrow, District Geologist.
Mr. J. B. Hill, R.N.
Dr. W. Gibson, D.Sc.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
} Geologists.

The field-work during 1910 lay in the north-western part of the Warwickshire Coalfield, the northern and eastern portion of the South Staffordshire Coalfield, and in the intervening ground. The last named is occupied mainly by Triassic rocks, but there are also present at the surface some beds which have hitherto been regarded as Permian, but the true relations of which are in doubt.

The North End of the South Staffordshire Coalfield.

In the northern part of the South Staffordshire Coalfield which is being resurveyed by Dr. Gibson and Mr. Cantrill, the Carboniferous rocks are so largely concealed either by Drift or by the Bunter Conglomerate which unconformably overlies them, that their structure and sequence are difficult to interpret by field-observation alone. Much information, however, has been obtained during the progress of coal-mining.

The Drift and Bunter, however, are both absent in certain localities. One of these areas lies near the north end of the

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coalfield in Beaudesert Old Park, where the highest workable coals and the associated rocks crop out at the surface. The latter are found by Mr. Cantrill to consist of soft argillaceous grey strata devoid of any bed capable of producing marked features on the surface. They contain several coal-seams which were worked at the crop many years before the time of the original survey of this area by Jukes (1853-1859), and of which little information is now obtainable.

Further to the south-west Dr. Gibson has found the Carboniferous rocks exposed again at the surface in the neighbourhood of Littleworth and Bridgtown. The strata here cropping out belong to a higher horizon than those referred to above. The most continuous sections are found in the brick-pits about Bridgtown, where a thickness of at least 600 feet can be measured before the beds become covered by the unconformable Bunter at Lodge Hill. Other exposures occur at Cheslyn Hay, Rumer Hill, and Littleworth. The predominant components of these high Coal Measures are marls and clays of a deep-red colour, mingled with bands of pale-yellow, brown, crimson, deep-purple and lavender-coloured clays. Lenticular beds of gritty sandstone, originally grey, but weathering red, are developed in the lower part of the series on several horizons. Higher up in the series sandstones become abundant and these are usually red even when unweathered. At Longhouse Tileries, Bridgtown, a seam of coal six inches thick, resting on grey fireclay, occurs about 300 feet above the base of the group. Carbonaceous clays and marls are also present in the Littleworth Clay-pits. Occasionally thin bands of highly calcareous mudstone, containing hardened pellets of red calcareous clay, but apparently unfossiliferous, recall the earthy Spirorbis Limestones of other Midland coalfields.

The eastern side of the northern end of the known coalfield is bounded by the Eastern Boundary Fault. This fault has been cut through at one point from the Brereton coal-workings, and red rocks, believed to be of Bunter age, have been met with. That the fault has a downthrow east in the Trias is thus proved; presumably it throws the coals also down in the same direction, but to what depth it is difficult to conjecture for a reason given later on. The coal-seams dip towards the fault for a considerable distance to the west of it.

The western limit of the coalfield, beneath the Trias, has not been located; but no evidence of a boundary-fault like that just described has so far been met with. At Cheslyn Hay, in the neighbourhood of the margin of the Bunter, a series of north-and-south faults bring on the highest red measures already referred to. One of them has a proved downthrow of 99 yards to the west and on the downthrow side the red measures still dip west. Thus so far the structure of the known field is essentially that of an anticline bounded by faults, more or less continuously on the western and entirely so on the eastern side.

The known coalfield of South Staffordshire differs from that of Warwickshire in not being terminated to the north by the meeting of two boundary-faults; on the contrary the coal-bearing measures rise gradually to the north-west and are cut off in succession by the unconformable Bunter Conglomerate. A boring

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at Fair Oak, near Rugeley, after penetrating the Bunter passed through a small thickness of Coal Measures and proved the presence of Millstone Grit and Carboniferous Limestone.*

In the Brereton area Mr. Cantrill finds that some of the faults are of pre-Triassic, others of post-Triassic age. Many which have been proved in the coal-workings, especially those having an east-and-west direction, appear not to affect the overlying Trias. On the other hand some of the north-and-south faults, though they displace the Trias, are much smaller in that formation than they are in the Coal Measures; the fracture has been effected in two distinct stages. To this class belongs probably the Eastern Boundary Fault, south of Rugeley. For at the surface this dislocation cuts all the subdivisions of the Trias, including the Keuper Marls, and is therefore so far of post-Triassic age. But while on the upthrow side the productive Coal Measures immediately underlie the Bunter, on the downthrow side there is reason to believe that some upper (barren) measures may be present below the Bunter, as though there had been faulting before the Bunter was deposited, as well as after. It is hoped that further proof of this hypothesis may be forthcoming later on. At Brereton, at the northern extremity of the exposed coal-field, the coals have long been worked by shafts, some of which are sunk through the Bunter Conglomerate. In this district 15 seams have been proved, of which the Shallow and the Deep Coals are the most important. Further south-west these seams are worked in conjunction with others.

The North End of the Warwickshire Coalfield.

The portion of the northern end of the Warwickshire Coalfield which has been surveyed during the past season is almost free from Drift and entirely free from any cover of Triassic rocks, so that the main structure can be made out from evidence seen on the ground. But at critical points the mapping becomes difficult owing to the absence of marked geological features, due as before to the persistent softness of the grey Coal Measures. The difficulty has been increased by the great amount of ashes and refuse that has been spread locally over the cultivated fields.

The soft grey measures in which the workable coals occur are succeeded upwards as before by thick masses of hard red and mottled marl, associated with bands of variable colour, grey predominating. A few thin seams of coal occur in the lower part of these marls, but they are of no commercial value and apparently do not occur so high in the series as in the case of the red beds previously described by Dr. Gibson.

Since the original survey of the district was made by Mr. Howell in 1858 numerous large pits have displayed more fully the characters of these marls. At some depth below the surface lenticular masses of rock composed of minute mud-pellets cemented by dolomite are not uncommon, though from their liability to disintegrate they are never recognisable at the surface. They often contain much larger red pellets, some of which are

* G. M. Cockin, *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 523.

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hard stained marl, while others are so rich in iron as to resemble hæmatite-nodules. These lenticles correspond in nature to those described by Dr. Gibson as occurring in the red beds of the South Staffordshire Coalfield.

Beds of soft yellowish-grey and brown sandstone occur within the red-marl group for a considerable height above the grey Coal Measures. Unlike those previously described by Dr. Gibson, they retain their grey colour when weathered and are never red. It would also appear that these sandstones are more abundant than in South Staffordshire and that they increase in the Warwickshire area as the north end of the coalfield is approached.

Though lenticular these rocks tend to occur at three fairly definite horizons, so that the drift-free area presents three steps in the landscape due to the alternation of marl and sandstone. The lowest step is formed by a more or less persistent sandstone close to the base of the marls. The next is due to the sandstones which overlie the marls worked in the great pits; this is singularly persistent to the south of Wilnecote Church and fairly well marked for some two miles to the north, though quite at the north end of the coalfield it becomes less distinct owing to the change in character of the beds already referred to. The highest step so far met with is formed by the group of sandstones which form the crest of the hill and a minor watershed on the Glascote road. It is on this step that the supposed outlier of Permian shown on the Old Series Map occurs.

Above this highest step there are more clays and marls, of considerable thickness and probably of good quality, for they were much worked in former days.

It has long been known that the northern end of the Warwickshire Coalfield is bounded by downthrow faults. The Eastern Boundary Fault was mapped by the late Mr. Fox-Strangways; the northern portion of the Western Boundary Fault has been mapped during the past season.

The Western Boundary Fault is not a simple fracture, but near its northern end gives off a branch which gradually diverges from the main dislocation till at Kettlebrook Colliery it is fully half a mile away. The two then approach again and reunite close to the bridge over the Tame at Fazeley. In no part of its course has the branch-fault a less throw than 100 feet, down west.

The main Western Boundary Fault is clearly traced in the area about Glascote and for some distance to the north, where it throws Keuper Sandstones against Coal Measures. In the Anker Valley still further north its position is obscured, but it has been located with considerable accuracy by a series of borings put down by Mr. Grayston of Amington Colliery and Mr. Ridsdale of Tamworth Colliery.

At Glascote Colliery the fault was proved close to the Glascote road, and in the Kettlebrook road the cutting of a sewer revealed Keuper Sandstone and nearly horizontal grey Coal Measures in close juxtaposition. There was singularly little sign of disturbance, and the impression given by this section alone would have been that the Keuper here had been banked rather than faulted against the Coal Measures. The horizontality of the

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latter had long been known, for Mr. Howell records that the Seven Feet Coal was at approximately the same depth all over this small area, then known as the Park Colliery.

From this point southwards the course of the Western Boundary Fault could only be investigated by digging through the refuse which had been spread over the fields. As a result a marl interbedded with the Keuper Sandstone has been found at a spot where its presence had never been expected, and eventually the fault has been fairly accurately traced to the road at Fazeley Bridge. South of this point again more of these marls have been dug up and it is now proved that the fault is situated in the bank of the Tame, considerably to the east of the position usually assigned to it.

At the north end of the coalfield, water, which is remarkedly saline in character, sweats through the coal at a distance of about a hundred yards from the fault, and it is not considered safe to work within this distance. But Mr. Howell makes no mention of any inrush of water when the Triassic rocks were pierced from the Park Colliery workings, near Kettlebrook; and practically no water comes in from the fault where it has been proved at the south end of Glascote.

Though there is no reason to doubt that the Western Boundary Fault is a downthrow west, we have at present no means of calculating its throw either in the Carboniferous or in the Trias. The measures rise towards the Boundary Fault, the general structure being that of a syncline, completely bounded by faults. Southwards the fold becomes more sharply accentuated so that near Dosthill the coals rise with a dip of as much as 30°.

Of the numerous coal-seams the Seven Feet Coal alone is worked at all the collieries. It differs in value locally, but no progressive deterioration in a definite direction has been evidenced.

The Double Coal is worked at Amington and the Four Foot at the Tame Valley pits. Other seams are worked in conjunction with some seams of clay, but not for separate sale. Formerly the Smithy Coal was worked in conjunction with the "white ironstone" but is now almost abandoned save for a little still taken at Glascote.

The clays of the grey measures and of the overlying marls are of considerable economic importance. Some of the clays of the former group are of extremely fine texture and to the touch much resemble French Chalk. Special bands of this material are mined by Messrs. Gibbs and Canning, at Glascote, and by Messrs. Skey and Co. at Wilnecote. In the overlying red marls there are some very dark clays, the colour of which is due, not to carbonaceous matter, but to abundant marcasite; when the clay is calcined this material is altered to red oxide of iron and imparts the well known terra-cotta colour. A bed of this type is worked close to Wilnecote Church.

In both South Staffordshire and North Warwickshire the grey measures associated with the workable coals are followed by thick masses of red marls, associated with sandstones. There is a

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strong presumption that these red beds correspond to the Etruria Marls of North Staffordshire, but their exact upper limit has still to be determined.

Red Rocks of Doubtful Age.

In 1859 Professor Jukes referred the red clays of Littleworth and Cheslyn Hay (Wyrley Bank) to the "Red Upper Coal Measures," and took them to be of the same age as the Red Coal Measure clays which are succeeded at the southern end of the coalfield by the grey measures of the Halesowen Sandstones, within which thin coals occur. But he considered the strata forming the long narrow strip of ground between the Bunter and those red-coloured clays to be of Permian age.

Since Jukes's time a large pit has been opened within this narrow strip, and the strata are identified by Dr. Gibson as also belonging to the Red Coal Measure clays, though they are at a higher horizon than those recognised by Jukes as Coal Measures. Some other strips of ground hitherto regarded as Permian lie outside the area at present surveyed.

The neighbourhood of Hints includes some rocks shown on the Old Series Map as Permian, which crop out on the western side of a north-north-easterly fault. The re-survey of the district has shown that these beds continue in a narrow belt for fully three miles, as far north as Tamhorn. A gravel-pit at the north end of Hopwas exposed some rather loamy and markedly calcareous red-brown sandstones, surmounted by a conglomerate. This remarkable rock contains abundant rounded fragments of limestone, crowded with crinoid ossicles and clearly of Carboniferous age. Mr. Wedd finds that the limestone resembles a rock which occurs *in situ* in the zone about the highest lava in Derbyshire, though doubtless a similar limestone may occur in other areas.

With these pebbles many others are associated, the most abundant being the quartzite which is such an important constituent of the Bunter Conglomerate. But in place of being rounded these are quadrangular, with the edges or angles only somewhat worn. All fragments other than limestone show a similar absence of rounding. The sandstones form a distinctive soil of a rich red-brown colour, and are separated by bands of bright pinkish-red marl.

This limestone-conglomerate is parallel to and closely underlies a conglomerate which is undoubtedly of Bunter age. It is not impossible therefore it is itself also of Bunter age. Moreover the Carboniferous Limestone itself lies next below the Bunter only some eighteen miles further to the north-east. The evidence, however, is not sufficient to justify a conclusion at present as to the true age of the Hints beds.

An outlier of red-brown sandstone, lying unconformably on the higher Coal Measures, at Stoneydelph, is shown on the Old Series Map as Permian. The value of the unconformity can not at present be estimated, and the identification of the rock must await the results of future mapping.

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Triassic Rocks.

A considerable area of Triassic rocks has been mapped and the following subdivisions met with:—

Keuper { Marl.
Sandstone and marl.
Bunter { Upper Mottled Sandstone.
Bunter Conglomerate.

Bunter Conglomerate.

The Bunter Conglomerate covers a large area about Cannock Chase, where it forms the most picturesque ground in the district. The formation consists as usual of alternations of variegated sandstones and conglomerate, the latter occurring for the most part in wedges and lenticles, some of which are of considerable dimensions. In the Rugeley area the most abundant pebbles are the well-known rounded quartzite-fragments, which are often of considerable size, ranging up to six inches or more; all show the characteristic pitting. In this area Mr. Cantrill has found that the coarser deposits do not extend to the base of the Bunter; the lowest beds consist of pebbly coarse buff sands and sandstones containing much detritus and many subangular fragments of the Coal Measures on which the Bunter directly rests.

Around Cannock the best exposures occur near Huntington Pumping Station and show the same characters. The less coarse basal beds have also been met with by Dr. Gibson in a sand-pit close to the Stafford Road, west of Old Fallow House; near Arnotts Grove, and again on the Old Penkridge Road and at Lodge Hill west of Bridgtown. At Old Fallow House portions of these beds have been worked for moulding-sand.

In the ground nearer Tamworth the Bunter Conglomerate is specially well seen in the Hopwas gravel-pit already referred to. Here it contains a considerable number of exceptionally large pebbles, some nearly nine inches long, and resembling bricks with the angles rounded. The fact that the quartzite-pebbles are often less well rounded than in some higher conglomeratic bands suggests a comparison with those of the "Limestone Conglomerate" previously mentioned. Among the pebbles there are many of Carboniferous chert, but apparently none of limestone. In some road-exposures near Hints Post Office, however, limestone-pebbles occur in patches.

Next below the conglomerate there is a red-brown sandstone strongly contrasting with the yellow sandstone of the beds above.

Upper Mottled Sandstone.

This subdivision is not well represented in the area so far surveyed. It is not persistently present about Rugeley, and on the east side of Cannock Chase it appears to have been overlapped by the Keuper. Further south between Chasetown and Hammerwich it emerges from beneath the Keuper and attains a thickness of several hundred feet. It is here a very fine-grained soft brick red sandstone, which at Ogley Hay has been extensively dug for moulding sand.

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Keuper Sandstone.

The Keuper Sandstone appears often at the surface but the outcrops are disconnected. Where mapped by Mr. Cantrill in the Rugeley area, the lowest beds consist of pebbly sandstones, not easily distinguished from the underlying Bunter. Further west these beds form the conspicuous escarpment of Etching Hill. The uppermost beds, immediately below the Keuper Marls, are buff and grey sandstones which in this district have been extensively used for building. The workable sandstones occur in distinct beds separated by marl-partings; the latter are, however, quite thin and the junction with the overlying Keuper Marls is fairly sharp.

About Lichfield this division of the Trias consists mainly of sandstone, generally of medium-grain and red-brown tint. Bands of calcareous concretions occur at varying horizons; sometimes they are aggregated, at others dispersed; they seem to be of the nature of "race." At the base of these sandstones, near Hammerwich, Mr. Dixon finds a conglomerate, about 5 feet thick, which increases westward and makes a marked feature in the Keuper Sandstone escarpment.

Much further north, nearer Brereton, where the Keuper Sandstone rests directly on the Bunter Pebble beds, the basal band is much less pebbly.

Towards the top of the group near Lichfield, marls between the sandstones increase in development so as to produce a passage into the overlying Keuper Marls.

In the Tamworth area not only are the marls developed, but the sandstones, where unweathered, are markedly calcareous. Pebbles of hard material such as quartz or quartzite are uncommon and at most horizons absent, but there are present curious calcareous beds composed of marl-pellets and spherical calcareous patches (possibly "race") set in a matrix of calcareous mud.

The lowest sandstones, so far as known at present, occur on the west side of the Western Boundary Fault, and are best exposed in the ground between the Glascote and Amington roads. In former days they were extensively wrought. The one quarry now open shows the rock to be markedly calcareous and very hard when quite fresh; most of it is red, but some bands or lenticles are almost white and less calcareous.

A considerable mass of white sandstone was cut through in making the new sewers from Glascote Church to Kettlebrook; at a small depth below the surface the rock was intensely hard. Sandstones, mostly white, but with bands of variable colour, were again encountered in making the sewer through Kettlebrook; these were still harder and markedly calcareous.

The marls between the sandstones are usually bright-red where seen at the surface; but borings always record the presence of green (or perhaps grey) marls. In one boring 50 feet of marl was passed through with only two thin partings of soft sandstone. Close to the canal at the Glascote Cemetery another thick bed of marl is quarried for brick-making and at Kettlebrook an old

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brick-pit proved a thickness of 60 feet of marl with mere partings of sandstone; this however may be the mass previously referred to.

The curious calcareous bands that at first sight closely resemble fine conglomerate are most often found at the base of the sandstones; thinner bands, probably lenticular, occur within the sandstones and in one case this material forms a distinct bed locally at least 8 feet thick. The resemblance to a conglomerate is of importance, for a boring close to the viaduct at the south end of Tamworth is reported to have passed through a "conglomerate." There can be little doubt that it was a bed of this nature in the Keuper and not, as might have been supposed, Bunter Conglomerate.

The thickness of the Keuper Sandstones is difficult to estimate as they are bounded by a fault. It is probably rather more than the 300 feet estimated by Mr. Howell.

Keuper Marls.

The Keuper Marls form a larger portion of the area surveyed than any other member of the Trias. In the northern part of the district Mr. Hill, Mr. Cantrill, and Mr. Dixon have all noted that these beds are rather of the nature of fine red sandy shales than true marls with cuboidal fracture. Much further south this character is not so noticeable, and what the significance of it may be is not yet clear.

These marls are worked for brick-making near Rugeley, where they are near the coal-pits; in other parts of the area the more valuable clays and marls of Carboniferous age found close to or in the coal-mines displace them, both in the Cannock and Tamworth Districts. In the area to the north of Lichfield, examined by Mr. Dixon, bands of brown or grey sandstone occur near the base of the Marls; they rarely exceed three feet in thickness and are similar to the thicker beds of the underlying Keuper Sandstone. Mr. Hill also has found thin and impersistent bands of sandstone for some distance up into the Marls.

Skerry bands, though not a conspicuous feature of the Keuper Marl in this district, are represented by thin bands of soft pale material. Some harder bands contain a considerable amount of dolomitic cement and occasionally of calcite; pseudomorphs of salt-crystals are also usually present.

Glacial Deposits.

One result of the past season's work is to suggest that the whole area has once been covered with Glacial Drift, though often there is nothing now left but scattered Bunter pebbles to support the suggestion. Two types of Glacial Drift are represented, one derived from the west, "the Western Drift"; the other derived from the east, "the Eastern Drift."

The Western Drift is essentially an unstratified gravel with an abundance of Bunter pebbles; but it contains also a variable amount of red clay mixed with it. In the Cannock area Dr. Gibson finds it to be a red gravelly clay, but nearer to Tamworth the clay becomes subordinate.

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Numerous boulders of granite and other rocks foreign to the district have been found by Mr. Cantrill some distance to the south and south-west of Rugeley, and in one part of the ground they are accompanied by a sprinkling of Chalk-flints. The granite-boulders are specially abundant about Norton Canes, and they have been met with in still greater numbers by Dr. Gibson further to the south-west. In the openings at the Longhouse Tileries, Bridgtown, and to the east of Cannock where a red pebbly clay fills a hollow in the Bunter, erratics abound. One type of granite which is especially common shows all the characters of the Dalbeattie Granite of the south of Scotland. Large boulders of a so-called "felsite" are also common. One block seen in a field on the west side of the London and North Western Railway, 750 yards south of Great Wyrley Colliery, measures 9 × 6 × 3 feet. Chalk-flints do not appear in association with these erratics, and Dr. Gibson has been impressed with the total absence of the distinctive Lake District rocks that are so abundant in the Drift of North Staffordshire. A considerable spread of similar gravelly drift has been mapped by Mr. Dixon to the west of Lichfield, where, however, it has been much dissected by small streams. To the north-east of Lichfield, in ground surveyed by Mr. Hill, the pebbles alone remain, but still further to the north-east continuous spreads of the Western Drift occur about Rolleston.

On the west side of the Tame near Tamworth, Mr. Barrow finds the Drift unevenly distributed over the large area of Keuper Marl. It occurs both on the plateaux and in the valleys. Here also it consists essentially of churned-up Bunter, without Chalk-flints or other foreign boulders.

The Western Drift may thus be summarised as being composed chiefly of churned-up Bunter material everywhere. In the western part of the area it usually contains more clay than in the eastern part; there also, granite and other foreign boulders are common and in one small district these are accompanied by Chalk-flints. Towards the east the latter disappear first and later the granite-boulders, till at last the drift contains little else than churned-up Bunter Conglomerate. Cannock Chase is alone capable of having supplied such an enormous mass of this material.

Glacial Sands and Gravels of the Western Drift.

Within the area more or less covered with this Bunter Drift there are several masses of well-bedded gravels, always banked against steeply rising ground. The largest of these, which has been mapped by Dr. Gibson, extends under the whole of Cannock town. Of several pits one at Oldfallow, north of the town, shows for the most part Bunter material and pebbles, but also several large blocks of sandstone, identical with the Keuper Sandstone of Penkridge, with an occasional erratic of granite, but no Chalk-flints.

Similar sands and gravels are dug in the pit at the south end of Hopwas already referred to. They are here more evenly

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bedded, but contain nothing that could not be derived directly from the Bunter, against the escarpment of which they rest.

Another pit, long disused, at Hints, shows gravel resembling more closely even than usual the Bunter Conglomerate.

The Eastern Drift.

The Eastern Drift was first met within the Anker Valley to the east of Tamworth. It here occurs mainly as well-bedded sands and gravels containing abundant Chalk-flints; an additional feature of these deposits is the smaller size of the Bunter pebbles and the increased amount of vein-quartz as compared with the Western Drifts. Further from the river-bed there are other gravelly deposits, very thin and more clayey, which may be projections from the true Eastern Boulder Clays. Remnants of them extend to Kettlebrook on the edge of the Tame Alluvium, from which it will be seen that the Tame practically divides the Eastern from the Western Drift at Tamworth.

Although the large hill of Carboniferous rocks to the south of Tamworth is practically free of Drift, the pebbles are scattered over it as elsewhere, and are even most abundant on the highest part of it. On the north-eastern side the Chalk-flints ascend for some distance.

To the north of Tamworth flints become abundant suddenly about Tamhorn. This place lies in a line with the hollow of Whittington, which suggests that the flints have been washed down a valley from the east; here they have crossed the Tame to the western edge of the Alluvium.

Much further north Mr. Hill has found abundant Chalk-flints in the Drift about Edingale and Croxall, and here again they seem to have been carried westward down the branch-valley of the Mease, for further north and north-east the Western Drift is present. It would thus seem that branch-valleys on the eastern side of the Tame have been utilized by Glacial streams, or possibly by small tongues of ice, for the transportation of the material of the Eastern Drift slightly into the area of the Western Drift.

Alluvial Deposits of the Anker and the Trent.

There is a considerable difference between the Alluvial deposits of the Tame and the Trent. The former, within the area surveyed, has no high terrace along its banks, but has formed an alluvial flat which is covered by floods, with a terrace rising two or three feet above it, which is also covered at times. A similar absence of any higher terrace is noted in the valley of the Anker, and it is clear that no serious deepening of the channels of the Tame and Anker has taken place in post-Glacial times.

The valley of the Trent presents different features. The First (or lowest) Terrace rises sharply to a height of from two to six feet above the Alluvium, and then slopes gradually upwards to as much as 14 feet above it. Next comes the High Terrace,

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generally some 35 feet above the Alluvium where it approaches most nearly to the river, but rising as it recedes from it till it attains a maximum height of about 60 feet. To the north and north-east of Lichfield, on the south side of the Trent, both terraces are broad, the First being about a mile wide and the High Terrace about a mile and a half wide. The latter here presents an unusual feature, for in place of ending off at the foot of rising ground its edge dominates the country further from the river, the ground actually sloping downward from it.

From this comparison of their fluviatile deposits it would appear that the Trent has in post-Glacial times deepened its bed to a greater extent than the Tame, as though it had at one time carried a greater amount of water. That this was the case was suggested when the country north of Leek, in North Staffordshire, was mapped, for there was found reason to believe that much of the water from the melting of the ice on the Cheshire plain must have come southward, cutting the great gap at Rudyard. When the ice had melted this supply ceased, leaving the gorge on a watershed. The suggestion is supported also by the contents of the gravels, for in the High Terrace, and less abundantly in the First Terrace, both Mr. Hill and Mr. Dixon have found many pebbles of granite and other igneous rocks some of which are identical with those in the North Staffordshire Drift, but which, as Dr. Gibson has pointed out, never occur in the Drift of the area under description. With them a small number of flints are associated, as might be expected, for Chalk-flints are peculiarly plentiful at the foot of the Rudyard gorge.

3.—London and S.E. District.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. R. L. Sherlock, B.Sc.
Mr. Henry Dewey.
Mr. C. N. Bromehead, B.A.
Mr. A. H. Noble, B.A.
} Geologists.

During the past season the six-inch survey of the eastern half of Berkshire was completed, a considerable area was done in southern Buckinghamshire, and a small tract was examined in Surrey. The district, though apparently simple, presents many interesting problems, for it lies on the southern limit reached by the ancient ice-sheet, where drainage and catchment areas were liable to great modifications owing to the accumulation of ice and snow. Through the deep freezing of the soil, which temporarily converted the sandy and gravelly lands, and the chalk hills, into areas quite impervious to percolating water, violent floods must have occurred, even with a rainfall no greater than at present. The new evidence, now being gathered, but not yet sufficiently complete for presentation, promises to throw much light on the Pleistocene, and possible Pliocene, history of the Thames basin.

As regards the Cretaceous rocks, most of the time of Messrs. Sherlock and Noble has been occupied in the mapping of the divisions and zones of the chalk, in order to form a more exact idea of the undulations of the strata, and of the value of this

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formation as a source of water-supply. The relation of the chalk to the overlying Eocene strata has also been studied. In this district, as far as we can ascertain, the Eocene beds rest directly on the Micraster Zones, except for a small area of Marsupite-chalk around Taplow. It is unfortunate that the phosphatic chalk of that locality, discovered some years since by Dr. Strahan, has proved to be of strictly limited distribution.

Mr. Bromehead's examination of the chalk hill on which Windsor Castle is built shows that it forms part of an oval inlier of chalk one and a half miles long, surrounded by a somewhat larger belt of Reading Beds, and with its axis ranging in the direction of west-north-west and east-south-east. This curious elongated dome cannot yet be connected with any system of disturbances in the neighbourhood, its strike is quite abnormal and it rises boldly out of the middle of a tertiary district of slight dips.

At the base of the Reading Beds Messrs. Bromehead and Noble find over nearly all the area a seam of clean glauconitic sand from 4 to 9 feet thick. This sand is probably of marine origin, as appears always to be the case with sands containing grains of glauconite, but no fossils could be found. As sands free from iron are in considerable demand for use in plaster, some of this sand was tested under an electro-magnet, with the result that the glauconite was removed with ease. This treatment would probably be costly in practice; but the fact is worth placing on record, as the sand occurs in a district becoming every year more thickly populated.

In the Bagshot area, surveyed by Mr. Dewey, the principal point of interest is the decided thickening of the Bracklesham Beds in a south-easterly direction. On the west they are only 40 feet thick; but at Ottershaw Park, about three miles south-west of Chertsey, they have thickened to fully 114 feet, with no top visible.

A deep boring at Ottershaw Park, now being made by Messrs. Duke and Ockenden for Mr. Eckstein, has yielded some curious results. Mr. Clement Reid, who has examined the site and the material brought up, finds that the boring gives a complete section down to and into the Chalk; but that, after penetrating 40 feet into ordinary white chalk, it met with nothing but a mixture of chalk with tertiary clay and sand for the next 211 feet.

The main divisions passed through up to the present are:—

	Feet.
Bracklesham Beds [in addition to 25 feet seen in the road-cutting above]	89
Lower Bagshot	124
London Clay	336
Reading Beds	100
Upper Chalk	40
Eocene Clays and Sands mixed with Chalk and Flints	211
Middle and Lower Chalk	315
Upper Greensand	45
Upper Gault with phosphatic nodules at base	108
Lower Gault to	188
	1,556

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This boring seems to have followed the line of a nearly vertical fissure which slightly diverted the tool, for at 900 feet the system of boring was altered, and the crown and chilled shot, cutting a solid core, was substituted for the percussion-tool. The boring immediately re-entered solid chalk, but had apparently passed through the Chalk-rock whilst in the fissure. Characteristic Melbourn Rock was met with between 927 and 936 feet. The base of the Chalk was reached at about 1,215 feet, and from this point to 1,368 feet fine-grained silty and more or less glauconitic sandstones (hearth-stones and fire-stones) represented the Upper Greensand and Upper Gault. At 1,368 feet darker and more clayey beds showed that the Lower Gault had been reached.

Mr. Sherlock's examination of the Clay-with-Flints of the High Wycombe District seems to indicate that a considerable part of it at any rate is glacial drift. Sarsens are abundant in this drift, which caps the high ground between Bradenham and Missenden. The stones are composed of hard white quartzite, which is a valuable building-stone and has been used in Windsor Castle. Owing, however, to the expense of finding and working the stone, it is now rarely used for buildings, but is cut into curbstones and setts for channels. The stones are at present being dug out at Walter's Ash, Bradenham and at Denner's Hill. The prospector bores to a depth of not more than 10 feet, and if he is fortunate enough to strike a stone he estimates its size by dropping the boring tool on it. The mass of the stone is measured roughly by the force with which the tool springs back after the impact. If the stone seems to be a large one, two or three borings are made round the first and the extent of the sarsen is thus estimated. A pit is next dug and the stone extracted by a crab, or, if very large, it is cut up *in situ*. The stones vary in size from small boulders to masses of several hundred tons and usually occur in groups. The clay in which they are embedded is used for bricks at Walter's Ash.

(B.) SCOTLAND.

The ground surveyed in the Highlands was arranged in two districts as follows:—

1. West Highland District, including Mull and South Morvern, under Mr. Clough, M.A.

2. North and Central Highland District, comprising parts of the counties of Sutherland, Perth and Inverness, under Mr. Hinxman, B.A.

In the West Highland District field work was continued in Mull, between Salen and Loch Spelve, and between Carsaig and Loch Scridain; in Morvern, on both sides of Loch Aline (Sheets 44 and 52). In the North Highlands, further progress was made with the mapping of East Sutherland in Sheets 102 and 109, and in the Central Highlands in Sheets 54 and 63.

The Coalfield areas were grouped in two districts:—

3. Shotts and Fauldhouse District, under Mr. Clough, M.A., where the revision of the Coal Measures near Mossend, Cleland and Shotts, and of the Carboniferous Limestone Series near Wilsontown was continued.

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4. Carluke, East Kilbride and Douglas District, under Mr. Hinxman, B.A. The re-examination of the Carboniferous Limestone areas near Carluke, East Kilbride and Stonehouse was continued and further progress was made with the Douglas Coalfield.

1.—West Highland District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A.
Mr. E. B. Bailey, B.A.
Mr. G. W. Lee, D.Sc.
Mr. B. Lightfoot, B.A.
} Geologists.

The ground surveyed in this district lies in the one-inch map 44, with the exception of a very small area in Morvern in the adjoining map 52, to the north.

Metamorphic Rocks and Foliated Lamprophyres.

Morvern.—A short traverse made on the coast south of Inninmore Cottage, has shown Dr. Lee that the gneisses are generally semi-pelitic, with some more siliceous bands. The strike of the foliation is mainly N.N.E. and S.S.W. They contain numerous intrusions: sheared lamprophyres, pegmatites, quartz felsites, a re-crystallised acid rock and foliated granite, together with Tertiary basaltic and trachytic rocks. The sheared lamprophyres are extremely numerous and may be of value in establishing the relations between this area and adjacent regions. These gneisses also form the two groups of small islands—Glas Eileanan and Eilean Rudha an Ridire—which lie between Inninmore and Craignure.

Ross of Mull.—During a short visit to Bunessan, Mr. Clough and Dr. Flett detected at Port Mor, on the west side of Ardalanish Bay (one-inch map 35) an intrusive sheet which is clearly older than the Ross of Mull granite, though much less foliated than, and evidently later than the common hornblende schists of the district. This sheet is cut by many veins of granite. In microscopic sections it proves to be a vogesite of peculiar type which has suffered considerable contact metamorphism. The foliation only affects the top and bottom parts, merely for breadths of a few inches near the surfaces, and it is approximately parallel to these surfaces, and thus in quite a different direction from the foliation noticed in the adjoining Moine gneisses. No foliation was detected in the granite, and it is believed that the sheet was foliated at the margins before the granite was intruded. It may be stated that Mr. Clough and Mr. Bosworth had previously found a somewhat similar pre-granite intrusion* also slightly foliated, on the west coast of Loch na Lathaich (one-inch map 43). Further examination in this locality has now disclosed other pre-granite intrusions of the same type. It is clear, therefore, that in the Ross of Mull we have two distinct sets of lamprophyres, each of which is well represented. The earlier

* 'Summary of Progress' for 1909 (*Mem. Geol. Surv.*), 1910, p. 27.

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set is older than the granite, and probably corresponds to the foliated lamprophyres of Colonsay and other parts of the Highlands.*

Carboniferous Rocks.

Morvern.—The Carboniferous rocks discovered by Professor Judd in 1877,† in which he found some plant remains characteristic of the Coal Measures, have been examined by Dr. Lee, and found to occupy a somewhat larger area than was formerly supposed. They stretch for about half a mile west of Inninmore Cottage and reach a height of at least 100 feet above Ordnance Datum. They consist of sandstone, shaly sandstone, sandy shale and impure fireclay, with occasionally thin lenticular coaly streaks. Two old day-levels, apparently of very ancient date, have been driven in shale at the back of the cottage, where coal was found, but evidently only in thin streaks. About 100 feet of strata are exposed above sea-level, but the total thickness is probably greater, since the junction with the beds referred to the Trias is obscure.

The plants collected were submitted to Dr. Kidston, who kindly furnished the following report:—

"The collection of fossil plants from Morvern contained the following seven species:—

Asterophyllites equisetiformis *Schloth. sp.*
Neuropteris gigantea *Sternb.*
Calamites suckowi *Brongt.*
Calamites cisti *Brongt.*
Calamites waldenburgensis *Stur.*
Stigmaria ficoides *Sternb. sp.*
Carpolithes sp.

"The first three on the list were represented by several specimens, while *Calamites waldenburgensis*, *Stigmaria ficoides* and the *Carpolithes* were only represented by one example each. None of these plants can be regarded as zonal forms, but as all are typical species of the '*Lanarkian Series*'‡ and there is an entire absence of any species specially distinctive of the '*Westphalian Series*'—above which horizon the beds cannot be placed—it is almost certain that the rocks which yielded these fossils belong to the *Lanarkian Series*."

Mesozoic Rocks.

Morvern.—Dr. Lee states that the basal portion of the Mesozoic sequence referred to the Trias by Professor Judd, is much thicker in the south side of the Glais Bheinn Plateau than in the region, near the head of Loch Aline, described by Mr. Maufe

* W. B. Wright 'The Two Earth-Movements of Colonsay.' *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv., p. 297.
C. T. Clough, 'Geology of Cowal' (*Mem. Geol. Surv.*), 1897, p. 121. At least one of the foliated intrusions described in this memoir was considered to be older than the Glen Fyne granite.

† 'The Secondary Strata of Scotland. Third Paper. The Strata of the Western Coast and Islands.' *Quart. Journ. Geol. Soc.*, vol. xxxiv., 1878, pp. 662, 684.

‡ This may be taken as roughly equivalent to the Productive Coal Measures overlying the Millstone Grit of Central Scotland. G. W. L.

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in the "Summary of Progress" for 1909, page 35, where it probably does not exceed 75 feet. A burn section, half a mile west of Inninmore, shows a thickness of some 320 feet, most of which consists of gritty sandstones and pebbly bands, with beds of red marly grit and cornstones near the top of the section. The passage to the Lower Lias is not shown here. The only place where it is seen is in an old quarry half a mile south of Ardtornish Towers. At this spot the series is capped by more grits passing upwards into a hard, white fine-grained calcareous sandstone containing numerous badly preserved lamellibranchs: *Ostrea irregularis* Munster, *Cardinia sp.*, *?Pteromya simplex* Moore, and a turreted gasteropod. None of these can be said to be of zonal value, but since the beds in which they occur belong lithologically to the underlying series into which they pass by gradual transition, while they are totally different from the overlying Lower Lias, it is perhaps permissible to regard them as of Rhaetic age. Between this sandstone and the Lower Lias limestones there are about 20 feet of strata, unfortunately everywhere obscured. But, from the fact that this portion of the section is marked by a zone of soft waterlogged ground, it may be inferred that the hidden strata are of argillaceous nature.

The Lower Lias of Morvern—seen on both sides of Loch Aline and in the cliffs south of Glais Bheinn—is divisible into two lithological groups. The lower consists of an alternating series—100 feet thick—of thin limestones and shale partings characterised by the extraordinary abundance of *Gryphaea arcuata* Lamk. The few ammonites obtained are too imperfect for accurate determination, but suggest an horizon comprising the Bucklandi zone and perhaps the two zones immediately above and below. The upper group consists of shaly beds, usually less than 100 feet thick, but sometimes reaching a thickness of 160 feet (at Ardtornish). The basal portion, soft and clayey, contains limestone nodules in which are found small, badly-preserved fossils, including a small ammonite which seems to be new to science. Above this horizon the shale is distinctly arenaceous and much harder, and, near the top, passes upwards into shaly sandstone. Fossils are rare, but the presence of *Asteroceras* aff. *smithi* (J. Sow.) and of *Amblycoceras* aff. *planicosta* (J. Sow.) proves that these beds belong to the Obtusus zone. Careful search along the outcrop has shown that this is the highest member of the Jurassic sequence in Morvern. The Obtusus Beds are everywhere in this region overlapped by the Upper Greensand or by the Tertiary lavas, as pointed out long ago by Professor Judd.*

The Upper Greensand consists of glauconitic sandstone, about 20 feet thick, the top portion of which contains such an abundance of the shells of *Exogyra conica* J. de C. Sow. that it becomes a sandy glauconitic limestone. It is interesting to note that at the base of the formation the sediment has an intensely green hue and is largely made up of glauconite. This, and the formation to be next described, have been traced on both sides of Loch Aline and above Ardtornish Bay; they die out east of the latter point.

* *Op. cit.*, p. 732.

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Overlying the Upper Greensand comes a massive white sandstone, generally 20-30 ft. thick, but occasionally thinning out altogether. It contains no fossils, but from its position above the Upper Greensand and below the Tertiary lavas we may infer that it represents some portion of the Chalk, presumably a small portion, since its lithological characters show that it must have accumulated rapidly. In his paper (*op. cit.*, p. 733), Professor Judd correlates it with the Middle and Lower Chalk of England.

Pennyghael and Carsaig District.—Mr. Lightfoot while surveying the area near Carsaig, on the south coast of Mull, found little to add to Professor Judd's published account of the Jurassic and Cretaceous rocks* except that the base of the Tertiary lavas, overlying the Mesozoic rocks, is faulted in several places.

The Cretaceous rocks first appear in the cliffs about two miles south-west of Carsaig and gradually rise in an easterly direction. The Jurassic rocks eventually appear beneath them, and behind Carsaig House the base of the basalts reaches a height of 600 ft. The ground is now obscured for about a quarter of a mile by a large landslip, and for some miles the Mesozoic rocks are not again seen in the cliff. Indications of a powerful fault that throws the base of the basalts down below sea-level again are observed on the shore and in the upper part of the cliffs.

Further to the east a small, badly broken patch of vertical Liassic rocks appears between two faults.

The palæontology of the Carsaig rocks has not yet been examined in detail.

Tertiary Rocks.

Pennyghael and Carsaig District.—Mr. Lightfoot states that at Carsaig the bottom bed of the Tertiary igneous rocks is a thin mudstone, which is overlain by a thick mass of basalt lavas rising to a height of at least 1,500 feet. Although, as previously mentioned, the base of the lavas dips to the westward near Carsaig, yet the rock terraces near the shore of Loch Scridain seem to have a gentle dip to the east, towards the centre of the island. In this district the terracing is not so regular as in the typical plateau country to the west, which may possibly be due to the metamorphism resulting from the plutonic centre and the floods of minor intrusions.

The minor intrusions are very varied. To the west of Pennyghael there is a marked absence of the north-west dykes. But we have here a series of sheets usually running a little south of west and dipping southwards at varying angles, often about 70°. The most abundant type has been identified by Dr. Flett as an olivine-free dolerite. The sheets are often glassy in a considerable part of their mass, and weather into sheaths and cores. Granophyres and pitchstones also occur, both as steep sheets inclining southwards and also as thin sills. East of the mouth of the River Leidle the north-west dykes become abundant, and a few of them are seen to cut the sheets.

* *Op. cit.*, p. 660.

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Still further to the east the amygdules of the lavas become epidotised, and the lavas assume a different character, being much paler in colour. These changes come on gradually, but the ultimate difference is so marked that Professor Judd* drew an arbitrary line separating the more eastern rocks from the plateau basalts to the west, and termed the former felstones. Just beyond the point at which this difference becomes noticeable, a series of intrusions of various types is met with. Most of these are dolerite, but sub-acid types and two large sheets of granophyre have also been detected. These various intrusions belong to the great ring of inclined sheets which has been mapped in other parts of the island, and no doubt the difference in character of the lavas is largely due to the metamorphism brought about by them. Near Kinloch many lines of crush are seen, along which gullies have been excavated for considerable distances, but the amount of throw, where it can be estimated, is only a few feet.

Salen District.—Mr. Wright continued the survey of the Salen District, and the chief results of his work are incorporated in the following report:—

In the "Summary of Progress" for 1909, p. 31, he gave some account of the mass of granophyre occupying the north-west quadrant of the Mull plutonic centre. It was there shown that a narrow outer belt of granophyre lying along the circumference of the circular plutonic area is separated from the larger mass within by a vertical "screen" of lava. This outer belt is almost certainly a distinct intrusion from that which it borders, and the separating wall of lava no doubt owes its preservation to its having been indurated by the first of these intrusions and thus enabled to resist destruction by the second. It was also stated that about a mile from its margin the roof of the inner granophyre was displaced by a powerful fault running parallel to that margin, the downthrow being towards the interior. It has now been ascertained that the difference in level of the roof outside and inside the fault is no measure of the displacement of the fault, for the granite outside the fault rose to a different horizon in the lavas from that inside. The roof of the granophyre outside the fault is composed of basalt lavas of the plateau type, that within the fault of alternating rhyolites and agglomerates with subsidiary basalts. This latter group of lavas is probably stratigraphically higher than the plateau basalts, for it is unrepresented outside the plutonic centre, which could hardly be the case if it lay beneath them. It thus appears, independently of the displacement of the roof, that the downthrow of the fault was towards the interior.

The above relation suggests, though it can hardly be said to prove, that the fault was in existence and probably moving during the intrusion of the granophyre. The granophyre outside the fault may also have been intruded at a slightly different period from that inside, but here again we have no direct evidence as to the relation of the two masses to one another.

* 'The Secondary Rocks of Scotland. Second Paper. On the Ancient Volcanoes of the Highlands and the Relations of their Products to the Mesozoic Strata.' *Quart. Journ. Geol. Soc.*, vol. xxx., 1874, pl. xxiii.

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The boundaries of the inner granophyre mass exposed on the slopes above Loch Ba and in Glen Cannel and its tributary valleys have now been almost completely mapped out. The upper surface of the mass has been found to be gently domed, the summit of the dome being situated somewhere near the head of Loch Ba, and the roof declining from that point in all directions. To the south-east, in the valleys at the head of Glen Cannel, the gently inclined roof gives place to a vertical wall, which can be followed down the hillsides for considerable distances, and is clearly a change in the nature of the junction of a different order to any of the minor irregularities observed elsewhere. To the north-east and south-west no change to a vertical wall has been observed, the roof appearing to descend beneath the level of the glens at a gentle angle. It is probable however that the relations here are the same as in the south-east. As regards the north-west side it is impossible to say whether the gently sloping roof extends north to the large fault or changes to a vertical wall before it reaches it.

In this part of Mull therefore there appear to be three more or less distinct masses of granophyre:—

(1.) A central plug, which may be termed the Glencannel Granophyre, having a gently domed roof and on one side, at any rate, a vertical wall, and lying within the north-west quadrant of the plutonic centre.

(2.) Another granophyre separated from this by a huge fault and forming a belt a little over a mile wide along the circumference of the north-west quadrant. This it is proposed to name the Beinn a' Ghraig Granophyre.

(3.) A further belt, a quarter of a mile or more wide, outside the Beinn a' Ghraig Granophyre, and separated from it by a narrow vertical wall of baked lava. The outer boundary of this belt is also a vertical wall cut right across the almost horizontally bedded plateau basalts. We shall refer to this mass as the Knock Granophyre.

Now as regards the north-east, south-east, and south-west portions of the periphery of the Glencannel Granophyre we find as we pass outwards from it in all directions that we cross first a narrow belt of lavas and then come once more to plutonic rocks. These latter are for the most part hybrids of granophyre and gabbro very similar to those found by Mr. Harker in Skye. They are separated from the Glencannel Granophyre by the belt of lavas just mentioned, which is generally not more than a few hundred yards in width. In the valleys at the head of Glen Cannel this belt is seen to be of the nature of a vertical wall and exactly comparable with that on the north-west side separating the Knock and Beinn a' Ghraig Granophyres. The hybrid belt seems everywhere to have risen considerably higher than the roof of the Glencannel mass. Its outer boundary is much obscured by the extraordinary abundance of the minor intrusions and has as yet been little investigated. Though for the most part only exposed in the valleys, this belt of plutonic rock almost certainly forms a complete ring round the north-east, south-east,

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and south-west sides of the Glencannel Granophyre. It may be named the Gaodhail Hybrid Belt. It is well exposed in the Gaodhail River above Gaodhail.

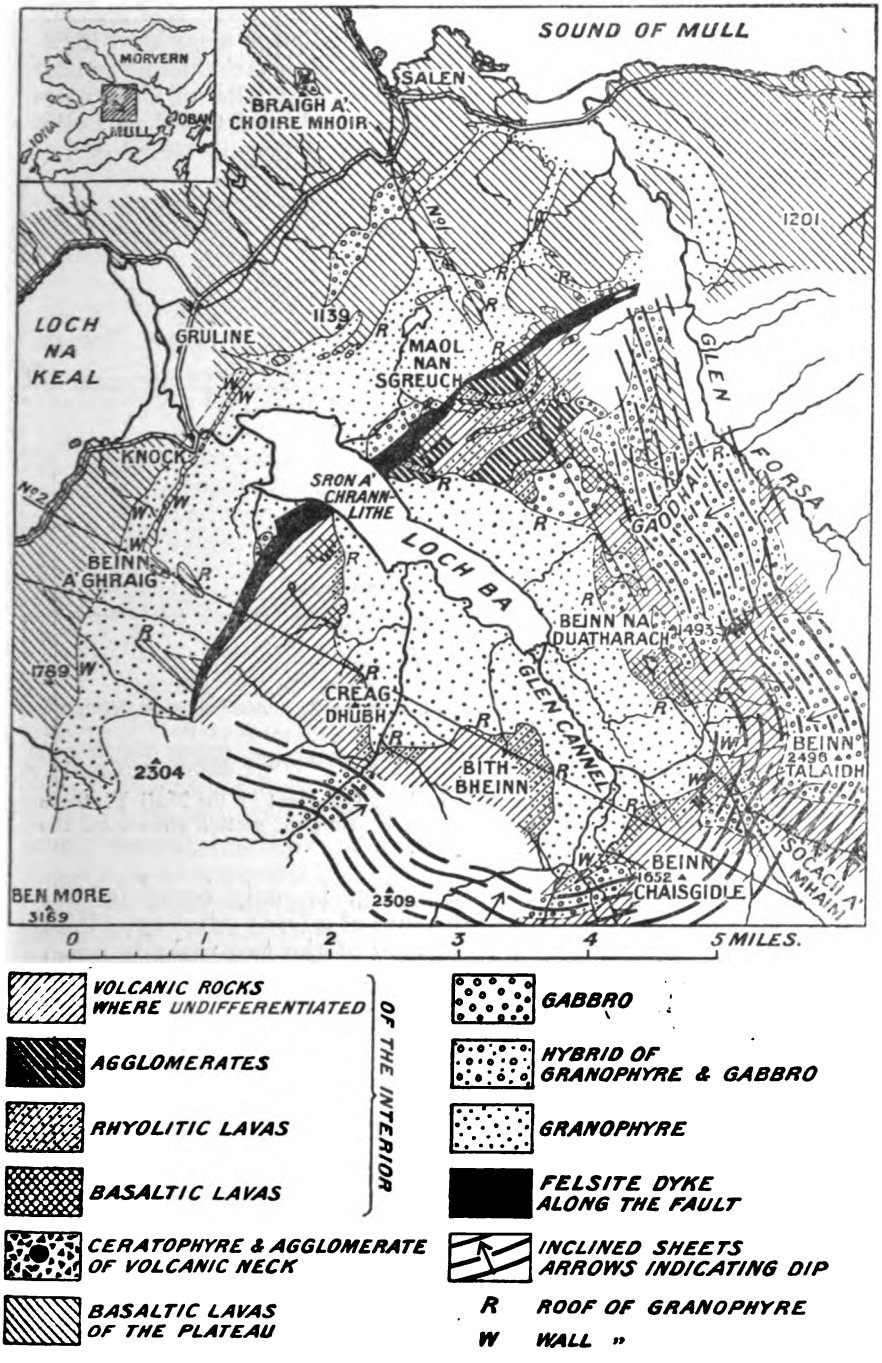

Fig. 1. Map of the North-West Quadrant of the Mull Plutonic Centre. All dykes omitted. Representation of the inclined sheets entirely diagrammatic.

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Now the central Glencannel Granophyre has nowhere formed hybrids with the gabbro, and in this respect it contrasts remarkably with the outer belt, which is mainly hybrid. It is interesting to note that the circumferential granophyre belts of Beinn a' Ghraig and Knock to the north-west have also formed hybrids with the gabbro, but the hybridisation is more local than in the Gaodhail Belt. Moreover there is a remarkable difference in the nature of the hybridisation between the Beinn a' Ghraig Granophyre on the one hand and the Knock and Gaodhail Belts on the other. The hybrids of the Beinn a' Ghraig Granophyre,

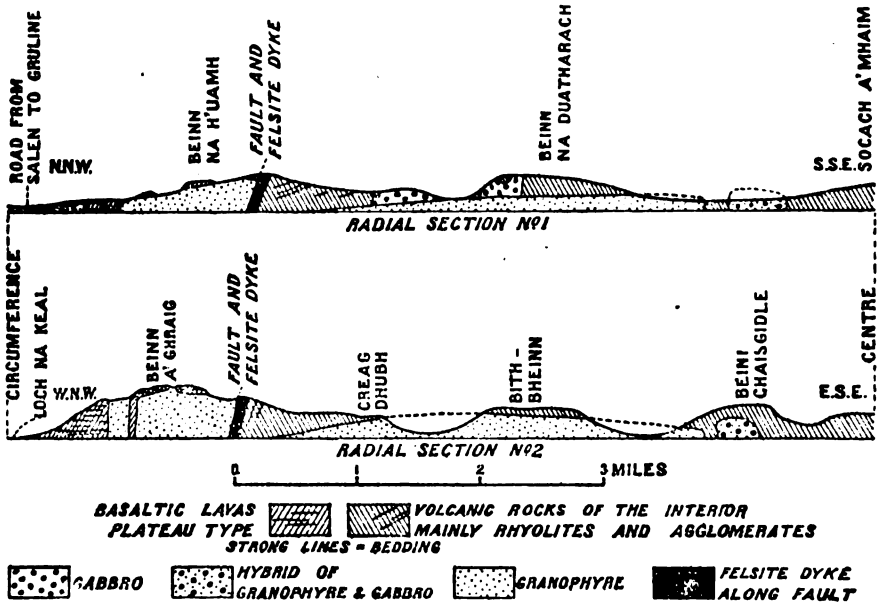

Fig. 2. Radial Sections of the North-West Quadrant of the Mull Plutonic Centre. Vertical scale the same as horizontal. Lines of section shown on the map, Fig. 1. All minor intrusions omitted.

which, as indicated on the map (Fig. 1), only occur in two localities adjoining the great fault, are of a less perfect type than those in the other belts. The mixing of the two rocks is much less complete, and angular lumps of undigested gabbro lie here and there in the granophyre. Such undigested remnants have as yet nowhere been observed in the Knock and Gaodhail Belts. Although the examination of these last mentioned belts is not yet completed we may sum up the results to date as follows:—

(1.) The central plug, termed the Glencannel Granophyre, has formed no hybrid.

(2.) The Beinn a' Ghraig Granophyre outside the great fault has formed imperfect hybrids with undigested lumps of gabbro.

(3.) The Knock and Gaodhail Belts have formed well mixed hybrids with, as far as we have seen, no residual undigested lumps of gabbro.

Some hesitation is felt as yet in drawing from this relation the conclusion that the outer belts are the older.

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The fault which separates the Beinn a' Ghraig Granophyre from the Glencannel Granophyre is accompanied along its entire length of five miles by an immense dyke of porphyritic felsite or rhyolite varying from a few yards to several hundred yards in width. This dyke is not quite vertical but dips outwards towards the periphery of the plutonic centre, having apparently been intruded along the line of weakness afforded by the crush breccia of the fault. In appearance it closely resembles the porphyritic rhyolite lavas of the interior, but several facts prove that it is, as Sir Archibald Geikie considered, an intrusion and not merely a massive lava bed dipping steeply towards the fault. These facts are briefly as follows:—

(1.) It can be conspicuously seen on either side of Loch Ba to maintain its approximate verticality for a range of over 1,000 feet from the level of the lake to the hill tops.

(2.) On Maol nan Sgreuch, to the north-east of Loch Ba, it is clearly proved to cut across the bedding of the rhyolites and agglomerates, which here dip towards the fault at an angle of 20 or 30 degrees.

(3.) On the same hill angular fragments of granophyre are included in the body of the dyke: they are obviously inclusions and not intrusive veins.

(4.) On the north-west slopes of Sron nam Boc, the hill three-quarters of a mile S.S.W. of Maol nan Sgreuch, the banded margin of the dyke can be seen cutting sharply across the fault breccia, which is here composed of granophyre with an odd fragment of basic igneous rock.

(5.) In the stream-gully which cuts through the dyke about three-quarters of a mile south-west of Sron a' Chrannlithe the banded margin of the dyke has caught up fragments of granophyre from the adjoining breccia.

The extraordinary mass of rhyolite, which forms one of the most conspicuous features of the north-west side of the plutonic centre, is thus proved to be of an intrusive nature. As regards the date of its intrusion it is clearly later than the granophyre and earlier than the north-west dykes, numbers of which can be seen to intersect it. It belongs therefore to the earlier portion of the epoch of minor intrusions, *i.e.*, to the same phase in the history of the plutonic centre as the basic inclined sheets. Of its relation in point of age to these sheets nothing is yet known, as they have nowhere been seen in contact with it.

The basic inclined sheets occupy a belt at least a mile wide around the periphery of the Glencannel Granophyre. This belt has approximately a U shape, its ends being conterminous with those of the above described felsite dyke and probably of the fault which the dyke follows.* It is obviously a matter of the greatest importance to determine clearly the relations at the two points where the inclined sheets approach the fault. One of these has not yet been investigated, the other is unfortunately

* The possibility that the fault may ultimately be traced in either direction beyond the limits of the felsite must, however, be kept in view.

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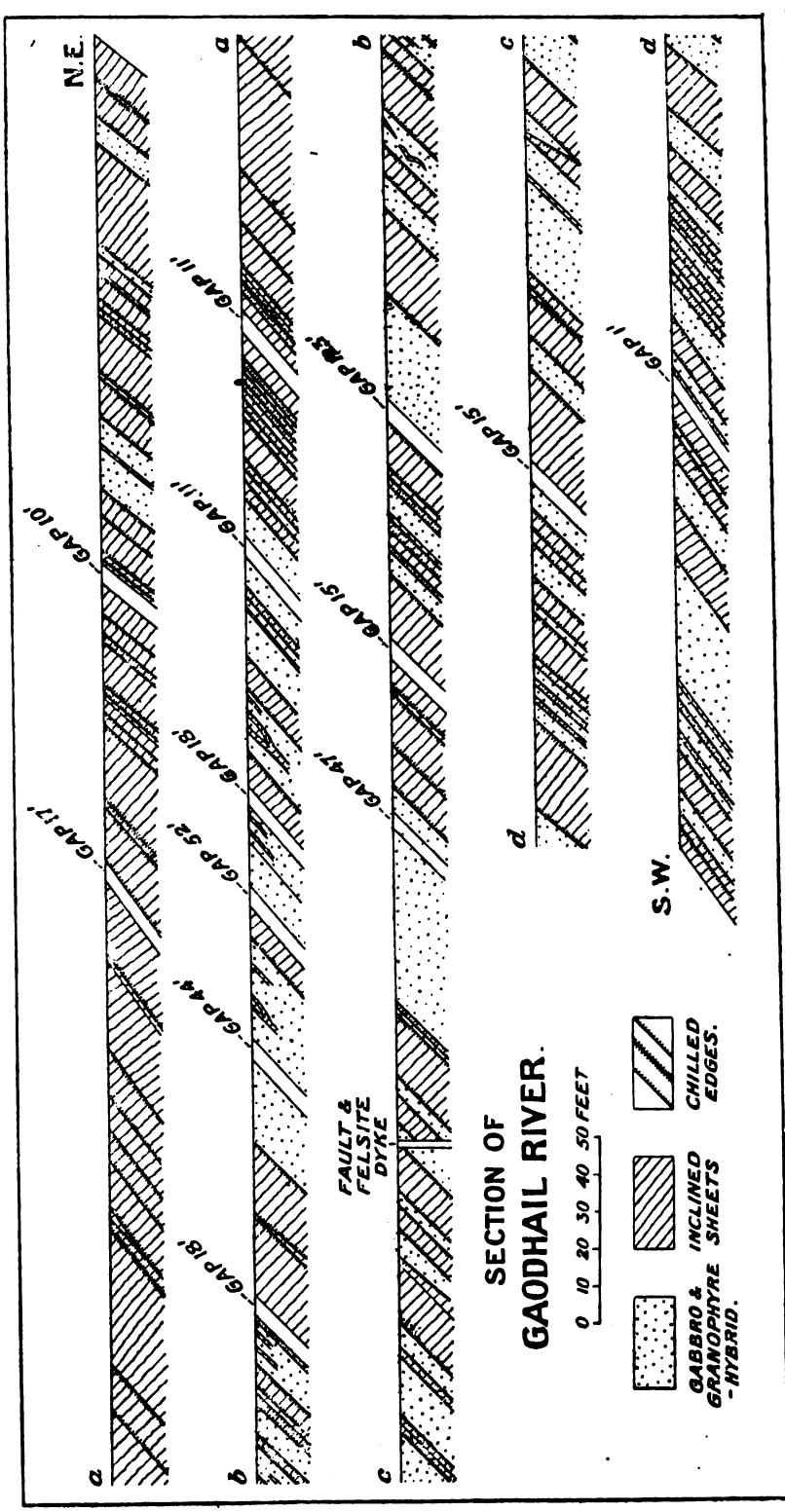

Fig. 3. Section of portion of the Inclined Sheet Belt exposed in the Gaodhail River, Mull. The chilled edges of the sheets are indicated where observed, but the smallness of the scale has necessitated their omission in a few instances.

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one of the most obscure areas in the whole of the island. The inclined sheets are seen outcropping in force in a stream section within a quarter of a mile to the south-east of the fault and striking at right angles to it. They do not, however, intersect the felsite nor are they found on the hill slopes to the north-west of it. This is all that is at present known as to their relation to the fault.

The conception, put forward last year, that the post-granophyre motion of the fault and the intrusion of the inclined sheets were contemporaneous and directly connected events, though still held to, requires some amendment in the light of the new evidence. This conception was based on the occurrence of the fault along that part of the periphery of the Glencannel Granophyre where there are no inclined sheets, and the fact that its breccia is cut by the north-west dykes and therefore belongs to that earlier portion of the epoch of minor intrusions to which the inclined sheets clearly also belong. It was at that time thought that the entire motion along the fault was of post-granophyre age, and, as the downthrow was towards the interior, the intrusion of the inclined sheets was connected, in spite of the great theoretical difficulty, with central subsidence. We now fall into line with Mr. Harker in regarding the inclined sheets as evidence of relative central elevation, and suppose that the post-granophyre motion of the fault (proved by the occurrence of the granophyre breccia) was in the opposite direction to the main throw, which was of earlier date. It is not necessary to imagine any absolute elevation of the central granophyre plug, for the latter may have merely stood firm while the general subsidence continued around it. The strain thus caused was eased on the north-west side by slipping along the old fault line, while, round the remainder of the periphery of the granophyre plug, it resulted in the production of the system of cracks into which the inclined sheets were injected.

As the abundance of the inclined sheets in the heart of the belt surpasses anything of a similar nature hitherto described, a section exposed in the Gaodhail River has been carefully measured with the object of getting an accurate idea of the proportion they bear to the country rock. This section in shown in Fig. 3. It runs at right angles to the strike of the sheets for about 600 yards. Of this distance 128 yards are obscured by gravel, and in the remaining 472 yards there occur 124 inclined sheets with 73 interspaces of hybrid rock. The total thickness of the inclined sheets is 660 feet, that of the intervening hybrid 342 feet. The country here is thus made up, 65 per cent. of inclined sheets and 35 per cent. of hybrid rock, giving a ratio in favour of the inclined sheets of nearly 2 : 1. In one part of the section for a distance of about 400 feet the proportion is over 12 : 1.

It is interesting to consider the amount of actual displacement implied in this enormous expansion. In the absence of any evidence to the contrary it is most natural to suppose the total displacement of 660 feet to be in the direction of the stresses, *i.e.*, perpendicular to the inclined sheets, which dip inwards at an angle of 45°. The vertical component of this would be about

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465 feet. That is to say that in the space of 472 yards examined there is a downthrow of 465 feet towards the outside of the belt. In view of the fact that the entire belt is considerably more than a mile wide, 1,000 feet would be a moderate estimate of the total downthrow, and a figure of the same order might be supposed to represent the correlated post-granophyre motion along the fault.

The completion of the mapping of the Glencannel Granophyre, and the tracing of the belt of inclined sheets which circles round it, have brought into prominence a very remarkable fact connected with the plutonic centre in general. This is its symmetry with regard to the direction of the attendant dyke system. If through the centre of the circular mass of mountains, which mark the plutonic portion of Mull, a line be drawn running north-west and south-east, most of the elements of this extraordinary complex of intrusive rocks will be found to be symmetrically disposed about this line. This symmetry is exhibited by:—

(1) the Knock and Beinn a' Ghraig Granophyre Belts;
(2) the fault which separates these granophyres from the Glencannel Granophyre;
(3) the Glencannel Granophyre itself;
(4) the Gaodhail Hybrid Belt which surrounds the Glencannel Granophyre;
(5) the general disposition of the gabbro in the island, as shown by Professor Judd;
(6) the folds which encircle the south-east of the plutonic centre;
(7) the felsite dyke which accompanies the fault;
(8) the U-shaped belt of inclined sheets which surrounds the Glencannel Granophyre.

The fact that the plutonic rocks share in the symmetrical arrangement shows that the stresses which controlled the intrusion of the north-west dykes were not in abeyance during plutonic times.

South-East part of Mull.—Mr. Bailey has further investigated the relations of the Tertiary breccia, which was referred to in last year's "Summary of Progress," page 30, as an important feature in the geology of the south-east part of Mull. Between Sgurr Dearg and the Lussa River this breccia rests upon a steep surface constituted, according to the locality, of schist, granophyre, sandstone or gabbro. All these rocks are greatly shattered for as much as three miles from their contact with the breccia, and the latter is in large measure made up of their commingled debris. The clear exposure here in Mull of "early" intrusions of granophyre and gabbro supplements the evidence obtained in the other Hebridean volcanic centres, where the existence of such intrusions has been inferred from boulders included in breccias or agglomerates. It is now thought possible that the Mull breccia in the Sgurr Dearg District may be occupying a vent comparable with the well known vents of the island of Arran and of Kilchrist in Skye. It lies within an arc of folded and faulted country in a manner which certainly recalls peculiarities in the position of the Arran and Kilchrist breccia.

As mentioned last year the portion of Mull in which the breccia occurs is flooded with inclined sheets of dolerite.

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Morvern.—On both sides of Loch Aline the Upper Cretaceous sandstone is overlain by about 6 feet of soft red or purple marl or mudstone. From its appearance Dr. Lee regards it as a sediment derived from a volcanic ash or mud.

True clastic sediments of Tertiary age have been detected at two localities only: namely on the coast south-east of the mouth of the loch, half way between the ferry and Ardtornish Castle, and on the side of the path leading to Inninmore, at about 1¼ miles W.N.W. of Inninmore Cottage. At the first of these localities they are represented by one or two thin beds of unfossiliferous yellow sandstone interbedded with the basalt, which here overlies the Gryphea limestone. In the second locality a dark sandstone, the field relations of which are very obscure, yielded a fragmentary fossil leaf. It is too imperfect for determination, but it was submitted to Mr. C. Reid who found that in its primary venation it greatly resembles oak.

In the area examined by Dr. Lee the Tertiary volcanic series exhibits features identical with those described by Mr. Maufe in the "Summary of Progress" for 1909, and call for no further description. It may, however, be mentioned that the Glais Bheinn plateau consists of about 20 flows, having a total thickness of 1,100 to 1,200 feet. The basalt dykes which are very numerous west of Loch Aline and on the western slope of Glais Bheinn diminish in number eastwards; most of them have a north-westerly course, but a few trend east and west. In one instance an east-west dyke is cut by a north-east one.

An intrusion of andesitic type forms reefs at low water mark, opposite Inninmore Cottage.

Sills and inclined sheets are thin and of rare occurrence.

Pleistocene and Recent Deposits.

Pennyghael and Carsaig District.—In the area surveyed by Mr. Lightfoot very little drift is seen, but boulders, chiefly of dolerite, occur scattered on smoothed rock surfaces in the valley of the River Leidle. Numerous glacial striæ show that there was a considerable flow of ice down Loch Scridain and also down the valley of the Leidle.

Raised beaches are seen on the shores of Loch Scridain and at Carsaig. The 25-ft. beach is well marked, has been brought under cultivation and has been used for the road. The 50-ft. and 100-ft. beaches also occur, but, owing to the terraced nature of the basalts, it is not often possible to determine the limits of these beaches with confidence. Both these higher terraces are well seen behind the Hotel at Kinloch, where they are composed of subangular shingle.

Morvern.—Erratic boulders are very numerous in the part of Morvern surveyed by Dr. Lee, but neither moraines nor boulder clay occur.

The 25-ft. beach forms a terrace at the head of Loch Aline and east of Loch Aline ferry, and at Ardtornish and Inninmore. A feature appearing to be due to a raised beach occurs 40 ft. above sea-level on the road-side 5¼ miles west of Loch Aline, and at Kinlochaline a conspicuous flat of sand and gravel occurs at 100 feet above sea-level.

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The talus at the foot of the great cliff on the southern side of Glais Bheinn is covered in many places by landslips. The largest of these, in Ardtornish Bay, is older than the 25-ft. raised beach.

Economics.

Carsaig and Bunessan.—The exposures in the tract of plateau basalts mapped by Mr. Lightfoot are not clear, the upper and under surfaces of different flows being rarely seen. They are usually markedly amygdaloidal and slightly red-stained, but no deposit of iron ore or bauxite has been noted.

A small coal seam, due no doubt to vegetable growth between two periods of eruption, has long been known on the slopes of Ben an Aoinidh. About 15 in. of bright coal can be seen (1910) but cannot be traced far. This has recently been the subject of some comment in the press, and the statement has been made that in the opinion of certain prospectors the interior of Mull is rich in excellent coal. This opinion, we believe to be quite erroneous.

Other Tertiary coals were also examined in 1909 by Mr. Clough and Mr. Bosworth in various places west of Ben an Aoinidh, but none is of sufficient thickness or value to work, except perhaps for strictly local purposes. One of these seams, locally called the Cadh'Easan Coal, is seen near the top of a cliff nearly half a mile slightly west of south of Airidh Mhic Cribhain. It is a bright coal lying nearly horizontal. At the time of the examination referred to, the maximum thickness visible was about a foot, but according to report a greater thickness has sometimes been exposed. The seam is usually overlain by a thin carbonaceous shale with laminæ of coal at the top, surmounted by a vesicular basalt, but the base of the basalt is very irregular and sometimes comes down so low that it cuts out most of the coal. It is clear that even if the coal had been generally thicker and better, the character of the roof would still have been greatly adverse to economical working. The basalt next below the coal is four or five feet thick, and is underlaid by another layer of bright coal 4 in. thick.

Another coal, sometimes worked for home use by the Shiaba shepherd, is seen near the bottom of a waterfall called Eas Dubh, half a mile east of Shiaba (one-inch map 43). This coal has for the most part a dull brown colour, and seems of a parroty nature. In one place it is two feet thick, but diminishes to 6 in. within a few yards. It dips steeply east and cannot be traced far.

Other crops of coal are known at Gowanbrae (Bunessan) and on the coast E.S.E. of Torr Mor, Ardtun Head, but these are no more promising than the others already mentioned. It is probable, indeed, that all the Tertiary coals of Mull are of very local development. As Sir A. Geikie has already said, "they seem to be always mere lenticular patches,"* and are also of inferior quality.

* 'Ancient Volcanoes of Great Britain,' 1897, vol. ii., p. 213.

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2.—North and Central Highland District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. R. G. Carruthers
Mr. M. Macgregor, M.A., B.Sc.
Mr. C. H. Dinham, B.A.
} Geologists.

Field work was carried on during the past season in East Sutherland by Dr. Crampton in Kildonan and the ground to the west of Kinbrace (Sheet 109); in the Ben Armine Forest by Mr. Macgregor (102, 109); and by Messrs. Anderson and Dinham in the neighbourhood of Lairg (102).

In Perthshire and Inverness-shire the survey of Sheet 54 was continued by Mr. Hinxman in the area between Loch Rannoch and Glen Lyon, and on the east side of the Moor of Rannoch, and by Mr. Carruthers on either side of Loch Treig.

With the aid of a grant from the Royal Society Research Fund several bores were put down, under the superintendence of Messrs. Carruthers and Tait, at Leavad, Caithness, to ascertain the nature and extent of the deposit of Neocomian strata referred to in the "Summary of Progress" for 1908, p. 75. The results of these operations are given in Appendix III., p. 80.

East Sutherland.

Highland Metamorphic Rocks and Associated Igneous Intrusions.

The greater part of the lower ground around Ben Armine and to the north of Loch Truderscaig, mapped by Dr. Crampton, is occupied by acid, hornblendic and biotite gneisses of Lewisian type. The structure of these rocks is granitic, like that of the granitised synthetic gneisses of the complex further to the east, described in last year's Summary,* and their frequently banded appearance appears to have been produced by successive stages of intrusion by acid and basic rocks and of foliation, followed by a final stage of granitisation similar to that met with in the Strath Halladale complex. It is possible, however, that this granitisation may be of earlier date than that of the Strath Halladale complex, since the latter has almost disappeared in areas between Ben Armine and the Strath Halladale granite.

The general strike of these gneisses is north-west or W.N.W., like that of the unmoved areas of Lewisian gneiss to the west, and the foliation planes are generally vertical or inclined at high angles to the north-east. Between Halmadarie and Loch a Choire (Sheet 108) they are, however, arranged in almost horizontal recumbent folds, which can be traced for 200 yards or more.

The upper part of Ben Armine consists mostly of folded pelitic gneiss (Moine Series) dipping gently to the north-west, while further to the east, and to the south of Loch Badenloch, the gneisses of Lewisian type give place to schists of Moine facies, with a N.E.-S.W. strike and gentle dip to south-east.

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* 'Summary of Progress' for 1909 (*Mem. Geol. Surv.*), 1910, p. 39.

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In spite of the marked difference in strike, the relations of the Lewisian and Moine types of rock are difficult to follow—partly on account of the drift covering, and partly by reason of the zones of shearing, with the N.E. strike of the Moine schists, which traverse the Lewisian rocks (recalling similar shear-zones in the unthrust Lewisian areas of the west), and so alter their character as to give them a strong resemblance to the schists of the Moine Series. The hornblende gneisses become biotite schists, while the massive granitic acid gneiss assumes the granulitic structure and schistosity of the Moine schists. Further complexity is introduced by the granitisation of both sets of rocks, a process which may, as suggested above, have possibly taken place at two different periods.

The main mass of the Strath Halladale granite lies several miles to the north-east of Ben Armine, but large sills and dykes of granite are common as far west as Loch Truderscaig, while *lit-par-lit* intrusion and granitisation have a still wider range. The effect of this granitisation on the Moine schists is to replace the granulitic by a granitic structure, and, where hornblende schists are also present, the resemblance of the whole assemblage of rocks to the gneisses of Lewisian type is very marked.

On the north side of the Helmsdale valley, the Scaraben quartzite has been traced south-westward from Craig Scalabsdale to Beinn Dubhain, and the band of pelitic schist by which it is flanked on the south-east has been followed into an outcrop of similar rock mapped formerly by Mr. Greenly. The junction of the two bands is marked by rapid alternations of siliceous and pelitic rock.

The ground surveyed by Mr. Macgregor in the north-eastern corner of sheet 102 is occupied by metamorphic rocks belonging both to the siliceous and pelitic members of the Moine Series, together with intrusions of acid granite. The intimate association of these rocks along the high ground east of the Brora River, has produced a series of complex synthetic gneisses similar to those mapped further to the north-east and described by Dr. Crampton in last year's Report.*

The local foliation or parallel structure of the granite may be attributed to flow movements during consolidation, there being no apparent deformation or augen-structure to indicate that the rock was subjected to the Moine earth-movements.

A similar complex of Moine schists and granite was met with by Mr. Macgregor in the area mapped in Sheet 109 to the east of the Shinsdale River. Here the rock exposures are few, the ground being mostly occupied by deep peat mosses showing the remains of two successive forest growths, the lower one of birch and the upper one of pine.

In the area examined by Mr. Dinham, between the eastern shore of Loch Shin and the River Tirry, the prevailing type of Moine schist is a somewhat siliceous quartz-biotite-granulite, with locally developed pelitic bands. A belt of garnetiferous hornblende schist with eyes of coarse amphibolite runs parallel to the

* *Op. cit.*, p. 39.

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general north-westerly strike of the surrounding schists, and is associated, on the Shiness peninsula, with pelitic schists and altered limestones.

The Shiness quarries, in which the limestone has been worked from time to time for local building and agricultural purposes, afford good sections of this zone. In the Old Quarry, 20 ft. of impure limestone, made up of rapid alternations of dark-weathering calcite and calc-silicate rock, is overlain by a quartzo-felspathic band and passes down into garnetiferous hornblende schist with numerous intercalations of greenish-white calc-silicate rock, the latter decreasing in number downwards from the limestone. In the New Quarry the limestone is purer, very coarse-grained and often of a pink colour. It occurs here in irregular beds, up to 7 ft. in thickness, between bands of calc-silicate rock, and is succeeded above and below by a few feet of very flaky biotite schist, followed by a considerable thickness of the hornblende schist which forms the principal member of the zone.

The siliceous schists in the ground to the south-west of Lairg, between the River Shin and Meall a Ghruididh, are permeated with intrusions of a basic hornblende-biotite-granite, from a few inches up to a quarter of a mile in breadth. This granite exhibits a varying degree of parallel structure which appears to be mostly protoclastic, and later than the foliation of the surrounding schists, with which, however, it corresponds in direction. The granitic material seems to have been introduced along the planes of foliation of the schists, and has isolated fragments of the latter. No instances have, however, been met with in which the foliation of the inclusion has a different orientation from that of the schist in the immediate neighbourhood. Near Braemore the granite passes into a highly basic rock largely composed of hornblende and biotite, without visible felspar, and showing little foliation. The rocks are also traversed by later acid intrusions, and the greater part of the hill of Meall a Ghruididh is formed of a coarse unfoliated aplite. This mass is cut off, on the south-east slope of the hill, by a line of crush, which has been traced for more than two miles in a N.N.E. direction.

The area mapped by Mr. Anderson on the east side of the River Shin is also occupied by Moine granulites, mostly of the siliceous type, and including a band of quartzite characterized by thin layers of magnetite.

Other rocks found in this area may be regarded as intrusions earlier than the foliation of the Moine schists. To these probably belong certain micaceous granulites, only distinguishable from the thin pelitic bands in the Moine Series by the abruptness of their margins. Others contain hornblende in addition to biotite, and one example has been met with of a rock with large crystals of hornblende in pink felspar, mainly orthoclase. An intrusion of hornblende-biotite-granite, continuous with the more basic of the two masses mapped last year by Mr. Macgregor,* also occurs to the south of Lairg. Near the foot of the Torroboll burn this rock shows marked parallel structure, but passes gradually

* *Op. cit.*, p. 39.

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into an entirely unfoliated granite. Thin veins of granitic material along the margins of the main mass are however intensely sheared. These much resemble the first type of foliated igneous rocks referred to above, which, it is suggested by Mr. Anderson, may belong to the same period of intrusion.

Old Red Sandstone.

The outlier of Old Red Sandstone which caps Beinn Dubhainn in the Strath of Kildonan, is found by Dr. Crampton to consist partly of a quartzite-breccia, and partly of a conglomerate made up of sub-angular fragments of granite, schist and quartzite. Some of the granite fragments are fully 2 ft. in diameter. Another outlier, partly bounded by faults, occurs to the east of Beinn Dubhain and in the bed of the head waters of the Allt Breac.

It shows the following sequence of strata:—

	Feet.
1. Red mudstones, somewhat flaggy and micaceous, with sun-cracks and gritty arkose bands; passing down into thin basal subangular conglomerate ...	350
2. Purplish-grey and greenish slaty flags	50
3. Conglomerate of subangular fragments of granite and schist in an arkose matrix	40

Pleistocene.

Most of the ground examined by Mr. Dinham is thinly covered with ground-moraine composed of very siliceous material, but well-defined retreat moraines occur along the sides of the Tirry valley. The local origin of the granite boulders so abundant around the foot of Loch Shin is confirmed by their absence on the shores further to the north.

Economics.

Opportunity was afforded to Mr. Macgregor, during his field work, of examining the recent extension of the coal workings at Brora in East Sutherland. The coal seam, which is of Lower Oolite age, is worked from a pit on the bank of the Brora River about 230 yards from its mouth. The seam is found at a depth of 253 ft. and dips a little east of south at an average angle of 14°-15°. The strata passed through in the shaft include sandy limestones, calcareous sandstones and bands of nodular limestone. The average thickness of the seam is from 3 ft. to 3 ft. 3 in., made up as follows:—

Very tough faky fossiliferous sandstone.	
Impure Coal and shale	6″
Coal	9″–1′
Sandstone Rib	0″–6″
Coal	1′–1′ 2″
Black curly shale with coal strains	0″–6″
Coal	½″
Shale.	

The coal is black, non-coking, and highly lustrous with dull streaks or "dirt bands." It is difficult to kindle, burns smokily, and leaves a high percentage of ash. Owing to the amount of

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pyrites present, there is a constant danger of spontaneous combustion. The seam is worked to the dip by a modification of the stoop and room method. It was formerly worked to the rise, but an outbreak of fire burnt out a large area of coal in that direction.

The annual output approximates to 6,000 tons, most of which is used locally, but occasionally the coal is sent to Wick or Inverness.

Bricks.—In connection with the Brora coal-workings there is a fairly extensive brickwork, where drain-pipes and bricks are manufactured from the stiff bluish boulder clay of the neighbourhood.

Perthshire and Inverness-shire.

HIGHLAND METAMORPHIC ROCKS AND ASSOCIATED IGNEOUS INTRUSIONS.

Further examination of the ground along the watershed between Loch Rannoch and Glen Lyon has yielded no evidence of any structural line separating the rocks of the Lochaber Series on the north side of the watershed from the siliceous and pelitic schists of the Lyon valley. The pure white quartzite of Croscraig, containing no mica, and correlated with the Glencoe quartzite, appears to pass gradually into a banded series of rocks of Moine schist facies, in which felspathic quartz-granulites, with a varying amount of biotite, alternate with semi-pelitic and pelitic schists and gneisses. The last named, however, differ in lithological character from the coarse, corrugated, garnetiferous pelitic gneiss which is associated with the limestone and Glencoe quartzite to the north.*

The siliceous Moine schists of this area are pierced by groups of N.N.E.-S.S.W. dykes, some of which may be provisionally classed with the lamprophyres, others with the porphyries, while there are some that show transitional characters between these two types. One of these intrusions, on the summit of Meall Bhuic, Glen Lyon, is a coarsely crystalline rock, described by Dr. Flett as combining the composition of a vogesite with a structure approaching that of a syenite.

The area surveyed by Mr. Carruthers on the west side of Loch Treig is of interest, as tending to show the relations between the rocks of the Lochaber Series, with their great recumbent folds, and the Moine schists which lie to the east and south-east.

At least three distinct rock types are present, viz.:—

(1.) Banded siliceous granulites (?Eilde Flags) with frequent partings of pelitic schist; they weather with a greenish tinge, are somewhat sericitic, and often garnetiferous. Traces of an earlier banding are often clearly visible.

(2.) Massive quartzite (?Glencoe Quartzite), shading below into a thin banded series.

(3.) Coarse pelitic schist or gneiss (?Leven Schists of Ballachulish), highly garnetiferous and homogeneous in texture, with few siliceous intercalations.

* 'Summary of Progress for 1908.' (*Mem. Geol. Surv.*), 1909, p. 59.

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Between Stob a' Choire Mheadhoin and Meall Mor these rock-groups are well exposed, arranged in a simple synclinal fold pitching steeply to the south-west, and with a complementary anticline on the west side. These folds are magnificently displayed on the north face of Stob Coire Easain.

The massive pelitic schists (3) form the rugged slopes west of Loch Treig up to the Stob a' Choire Meadhoin ridge. The banded flags (1) appear in the centre of the quartzite syncline, and, north of Meall Mor, can be followed round the nose of the complementary anticline into the ground west of Stob Coire Easain.

North of Stob a' Choire Mheadhoin the quartzite (2) dies out completely, and groups (1) and (3) are in juxtaposition. This result has evidently been brought about by an extensive "slide," since the quartzite is 700 or 800 feet thick on Stob Coire Easain, only a mile away.

North of Coire na Eabaig pelitic schists are frequent in group (1), but can be readily distinguished from those in group (3).

On the east side of Loch Treig massive siliceous granulites succeed the pelitic schists (3), but apparently form an additional member in the sequence, as they differ in several respects from the siliceous members of the banded flags north of Stob Coire Easain.

3.—Shotts and Fauldhouse District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. E. M. Anderson, M.A., B.Sc. } Geologists.
Mr. B. Lightfoot, B.A. }

Carboniferous Limestone Series.

Middle Coal-bearing Group.—In the area revised by Mr. Lightfoot at Wilsontown the section of this group is as follows:—

	Fms.	Ft.	In.
Index Limestone:			
Strata (dross coals in upper part)	22	0	0
Fireclay Craw Coal	0	1	10
Strata	5	0	0
Quarry Coal	0	1	0
Strata	5	0	0
Main Craw Coal	0	1	10
Strata, 20 in. to 14 ft., average	1	2	0
Main Coal	0	3	10
Strata, 10-14 fms., average	12	0	0
Blaes with four ironstone bands (Hogg Fence or Maggie Bands)	4	0	0
Strata	11	0	0
Wilsontown Gas Coal, 10 in. to 20 in., average ...	0	1	3
Strata	2	0	0
Coal	0	0	11
Strata	6	0	0
Coal	0	1	4
Strata	14	0	0
Limestone	0	1	3
Strata	0	3	0
Coal	0	1	6
Strata	20	0	0
Limestone (Hosie)			

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The field is cut off to the south by a large east and west fault, only proved in a few places, the throw of which is supposed to be about 100 fms. It is seen crossing the Dippool Water at Pool Bridge and in workings at Pool, where it is associated with a dolerite intrusion.

To the north of the fault are two synclines with a low and irregular anticline between, and the Main and Gas Coals lie in both these basins. The Gas Coal was much sought after and is practically all taken out from the Haywood Basin, but it became thinner to the west and was not worked beyond Cleugh. The coals below the Gas Coal are inferior, and attempts to work them have failed.

The Hogg Fence Ironstones were formerly worked in a considerable number of shallow pits in the Wilsontown District, for the supply of the Ironworks. The sandstone, known as the Quarry Rock, immediately above these bands, was at one time used for furnace hearths. Although in most places rather faky, it occasionally becomes a good building stone.

The Main Coal is almost exhausted in the Haywood Basin, but is worked at present on a large scale at Wilsontown by Messrs. Wm. Dixon, Ltd. The coal is generally easily wrought, but in some places a band of thick stone runs through the middle of the coal, and in others a band of Gas Coal, forming a very bad holing, occurs near the base. The coal is a good coking coal, and an extensive bye-product coking plant is in operation. The Fireclay Craw Coal has been tried at Haywood, Cleugh and Backshot, but was not a good subject. Owing to the fact that the Main Coal has been taken out beneath it, it is doubtful whether it can ever be profitably worked.

Upper Limestone Group.—In the area revised by Mr. Lightfoot little information has been obtained about this division. The section is, approximately:—

	Fms.	Ft.	In.
Levenseat Limestone	1	3	0
Strata	30	0	0
Calmy Limestone	1	0	0
Strata	28	0	0
Gillfoot (Orchard) Limestone	0	1	6
Strata	27	3	0
Climpy Gas Coal	0	0	7
Strata	9	3	0
Index Limestone	0	4	6

The Index or Climpy Limestone has been worked all along the western crop, which is now marked by a deep trench. It was of fairly good quality and used as a flux at the Wilsontown Ironworks.

A small amount of the Gas Coal was worked at Climpy, but was too thin to be profitable.

The Levenseat Limestone dies out westwards.

Millstone Grit.

From the report on the Coal Measures in the sequel (p. 49) it will be seen that the best line for the top of the Millstone Grit

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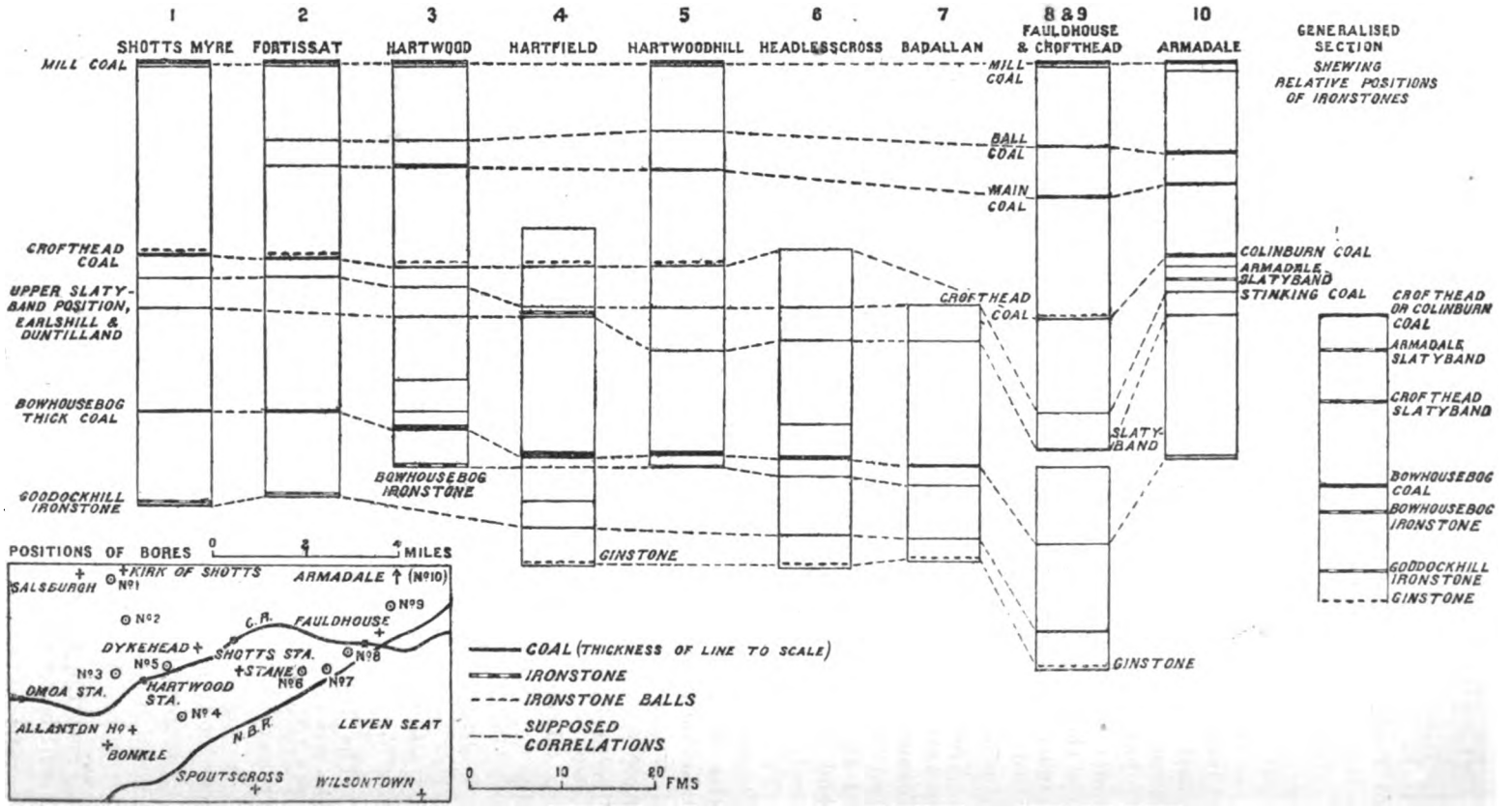

Fig. 4. Bore Sections near Shotts and Armadale.

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is not yet clearly defined. Mr. Lightfoot states that in the area between Shotts and Wilsontown the general section is as follows: —

	Fms.	Ft.	In.
Crofthead Slatyband Ironstone.			
Variable strata, mostly sandstone	20	0	0
Ginstone (Ironstone) and strata	0	4	0
Strata	15	0	0
Curdly Ironstone and strata	0	3	0
Strata	10	0	0
Levenseat Limestone.			

Both the ironstones indicated in the above section were in the past worked and sought after, but the Curdly was in especial request. Both of them seem, however, to be very irregular, and to have been missed in numerous bores wherein they were with some reason expected.

The Curdly Ironstone is a bed of clay ironstone balls lying in fireclay, below sandstone, and the pavement is composed of a "block" of bastard limestone, 16 in. thick. This limestone is found in all the old furnace refuse heaps and is full of Orthotetids.

The clay ironstone known as Ginstone or Thomson's Balls was formerly worked, for the Wilsontown Ironworks, in numerous shallow pits on the south side of the Breich Water. The balls lie in a bed of clay about 4 feet thick and contain a high percentage of iron.

Coal Measures.

In the area revised by Mr. Lightfoot, near Shotts, various ironstones, very local in character, occur near the base of the Coal Measures. Of these the Slatyband Ironstones of Crofthead and Armadale have been formerly taken as the base line of this group, and the latter has been correlated with the Goodockhill Ironstone. Thus Dr. Grossart* states that the Crofthead and Goodockhill bands are the same, that each is characterised by a marine fauna, and that the Bowhousebog Ironstone is 17 fms. above them. A large number of bores have been collected by Mr. Lightfoot, in order to find out constant horizons to be used as indices for the ironstones. A few of these bores are shown in the diagram (Fig. 4).

Beginning with the Armadale and Crofthead sections we find that the Colinburn Coal of the former corresponds with the Crofthead Coal. The Armadale Slatyband is unrepresented in the latter section, but the Stinking Coal is a constant feature, and owes its name to its pyritous character. A thin coal below the Stinking Seam in the Armadale District passes laterally into the Slatyband Ironstone of Crofthead, which is thus seen to be two or three fathoms below that of Armadale. Very few bores go below this position in this district, but such as do occur show coals which may be correlated with the coal and ironstone seams known further to the west.

* Grossart. 'On the Upper Coal Measures of Lanarkshire.' *Glasg. Geol. Soc. Trans.*, 1871, vol. iii., p. 96.

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The Mill, Colinburn and Bowhousebog Coals are constant, whilst westwards the Ball and Main Coals become generally thinner or die out, and the ironstones are very variable. At Hartwoodhill the Bowhousebog Coal and Ironstone are seen beneath the position of the Crofthead Slatyband. At Shotts Myre we have the typical section of the Duntilland field, where a rich basin of Goodockhill Ironstone was worked. Here a thin coal is seen, which is correlated on the one hand with the Upper Slatyband Ironstone worked at Earlshill, and on the other with the Crofthead Slatyband. At Shotts Myre also the Bowhousebog Coal is represented by a thin coal, which is separated from the Goodockhill Ironstone by a greater distance than that between the Bowhousebog Coal and Ironstone at Bowhousebog. No definite representative of the Bowhousebog Ironstone is seen at Shotts Myre. No bores have been obtained which go below the Goodockhill position at Shotts Myre, but eastwards this ironstone seems to pass into a coal, and a little below it the Ginstone, formerly worked by Crofthead and Handaxwood, appears.

From the foregoing sections it is inferred:—

(1.) That the Armadale Slatyband Ironstone is above that of Crofthead.
(2.) That the Crofthead and Goodockhill Slatyband positions are not the same.
(3.) That the Bowhousebog Ironstone is certainly below that of Crofthead.
(4.) That the Goodockhill Ironstone is probably still lower.
(5.) That the Ginstone position is probably just below the Goodockhill Ironstone.

The Bowhousebog Thick Coal is of inferior quality, and a trial pit sunk to it a year or two ago found it much ribbed by blaes and stone and not worth working.

Mr. Anderson states that the Goodockhill Slatyband Ironstone is no longer wrought near the farmhouse of that name, but a fireclay is being mined at an horizon 10 fms. above it. On the Tillon Burn, north of Muirhouse, a Slatyband Ironstone has been wrought which contains *Carbonicola*, and is thus different from the Goodockhill seam, which, as stated by Grossart, contains a marine fauna. In the burn section the ironstone is seen to be overlain by several thick sandstones, with thin coals and fireclays, all of which lie some considerable distance below the position of the Lower Drumgray Seam.

Blackridge.—The area between Blackridge and Polkemmet was almost untouched at the time of the original survey, but the Armadale Main Coal has now been extensively wrought, as well as, to a minor extent, the Coxrod or Lower Drumgray. Mr. Anderson reports that this area is comparatively unaffected by faults.

Mossend.—Mr. Clough has obtained a little additional information about an obscure area between Mossend and Milnwood House. The workings of the Milnwood Colliery (Coltness Iron Co., Ltd.), on the west side of this area are at a considerable depth, the Splint Seam near the house being about 100 fms. below ground. Yet in an old pit 330 yds. east of the house the same

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seam is only 12 fms. deep. In an old day-level which starts at the side of the South Calder south-east of the house, and proceeds in a N.N.E. direction, several faults inclining west were cut on the west side of the old pit. These faults are no doubt the chief cause of the increased height of the Splint Seam in the old pit. About half a mile further north a fault with a supposed large downthrow to the west has been met in working eastward, and this probably continues in a nearly south direction to one or other of the faults in the old day-level.

The measures on the east side of the above fault retain their elevated position only for a short distance, for about a quarter of a mile south-west of Mossend Station another big fault, striking north-west, throws them down again to the north-east, so that in an old pit (No. 4) a third of a mile south of Mossend Station the Splint Seam is at a depth of 85 fms., in spite of the normal rise of the beds towards the north-east.

Sections of considerable interest are seen in parts of the Thankerton (or Legbrannock) Burn, which flows north-west through Mossend. In one of these, about 50 yds. S.S.E. of Thankerton House, a 5-in. band of sandstone is seen to be full of remains of lamellibranchs—which appear to be rarely found in sandstones. The stratigraphical position is probably about 150 ft. above the Ell Coal. In another place, 300 yds. S.S.W. of Legbrannock, the Musselband which comes above the position of the Airdrie Blackband Ironstone is well exposed: it is, as usual, largely composed of bands of impure ironstone and parroty shale.

Intrusive Igneous Rocks in the Carboniferous Formation.

Mr. Anderson reports that the Northrig dolerite dyke, which runs east and west about a mile to the south of Armadale, has been traced, in colliery workings, two miles further west than it was previously known, and may have some connection with the Westcraigs sill, which shifts its level abruptly along it. The latter sill has affected the Coxrod Coal, 40 fms. below its base, but its influence does not generally cause deterioration in the Main Coal, which has been wrought to some extent beneath the present outcrop of the dolerite.

The dolerite sills of this district have been intruded in a very irregular manner. Besides sudden alterations of level, they seem to thin out very rapidly, while it is probable that different sheets may overlap.

Near Shotts Kirk the most southerly of the great Caldercruix group of Whin floats appears. Mr. Lightfoot states that the Shotts Furnace, Laigh and Smithy Coals are worked beneath it at Fortissat, and that all show abnormal characters. The Furnace Coal becomes a first class steam coal, and analyses, furnished by Mr. Danks and the Shotts Iron Co., show that near the whin the coal has a much higher percentage of fixed carbon and less volatile matter than the same seam a mile or so away.

About a mile north-east of Wilsontown a dolerite intrusive in the Carboniferous Limestone Series occupies an area of about an eighth of a square mile. It is not well exposed, but seems to be a sill folded with the strata.

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In mines in the Morningside Coalfield several whin dykes have been found in close connection with faults. Their general direction is nearly east and west. A small exposure of dolerite of uncertain relations is seen with the large east and west fault crossing the Dippool Water at Pool Bridge.

Economics.

Mr. Anderson states that the workable part of the sandstone wrought at Auchinlea, about four miles south-east of Coatbridge, lies from 5 to 15 fms. above the Virtuewell Coal. It is thick-bedded and fairly uniform in character, while there are few joint planes. The process of quarrying is begun by means of Ingersoll-Sergeant channelling machines, which were first used in Scotland in the Auchinlea quarries. Vertical grooves 8 or 9 ft. deep are driven from a horizontal surface, so as to divide the sandstone into blocks which are afterwards removed in the ordinary way by wedging. There is a very heavy cover of boulder clay which is utilised for brick-making, while odd corners of sandstone are ground up into building sand.

4.—Carluke, East Kilbride, and Douglas District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. R. G. Carruthers
Mr. M. Macgregor, M.A., B.Sc.
Mr. C. H. Dinham, B.A.
} Geologists.

Mr. Carruthers reports that the revision of the East Kilbride basin has now been completed.

The fine natural section exposed along the course of the Rotten Calder Water has been carefully examined and measured, and we have now a full knowledge of the components of the lower half of the Carboniferous Limestone Series and the upper part of the Calciferous Sandstone, as developed in this part of Scotland. In addition, the numerous natural and artificial sections found in other parts of the district have enabled the stratigraphical variations to be followed in detail.

The correlations with the type district of Hurlet, that have thus been made possible, are remarkably complete. At Hurlet, in the strata between the "Black Metals" and the Lady Ann Coal, at least 20 distinct horizons are known. Of these no less than 17 have been recognised with certainty in the East Kilbride District, and of the remaining three, one only—the Hurlet Coal—seems to be entirely wanting.

The following table of vertical sections (Fig. 5) shows the correlations now established between the Hurlet area and the western and central parts of the East Kilbride basin. The variations in these sections are chiefly confined to the thickness of the beds of sandstone and blaes; the limestones, with one or two exceptions, are remarkably constant in character and composition.

Numerous sections of the Upper Limestone Group are seen in the east side of the basin. The whole group has only about half the thickness obtaining in the Glasgow District, but the four

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main limestone horizons (Index, Lyoncross, Orchard, Calmy) have been recognised. The original Survey correlation of the Limekilnburn Limestone with the Gair or Calmy Limestone, has been confirmed by the discovery of the characteristic lamellibranch *Edmondia punctatella*, in the shales beneath the limestone.

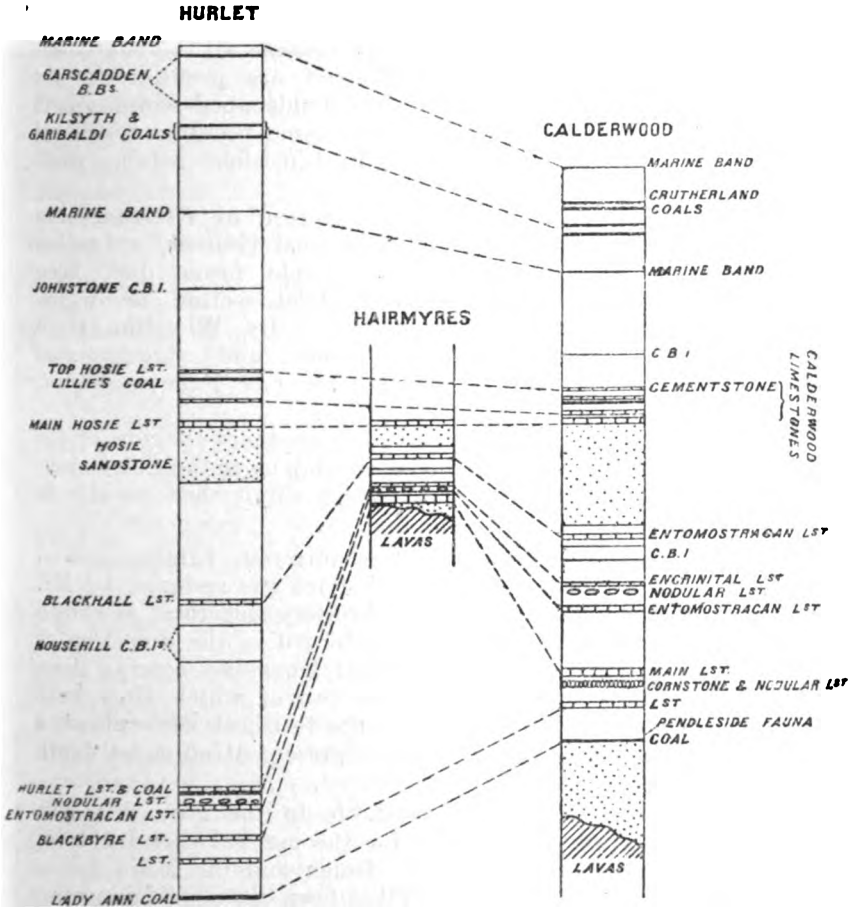

Fig. 5. Comparative Sections of Strata in the districts of Hurlet and East Kilbride, scale 200 feet to 1 inch.

The main results of the revision may be summarised as follows:—

(1.) The Limekilnburn Limestone is the equivalent of the Gair or Calmy Limestone of the Central Valley.

(2.) The Crutherland Coals (whose outcrop has been laid down on the map) are in the position of the Kilsyth Coking and the Garibaldi Coals of the Glasgow District: a marine band found about 40 ft. above them near Crutherland, probably represents the similar band in the "Black Metals."

(3.) The Calderwood Limestones represent the Hosies, the Cementstone being identical with the Top Hosie Limestone; the Hairmyres Limestone is the Main Hosie.

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(4.) The Main Limestone of Thorntonhall is equivalent to the Blackbyre Limestone of Hurlet, and the top post in the Thorntonhall quarries, together with the underlying beds of nodular and entomostracan limestone, represents the Hurlet Seam itself. Special attention is drawn to the fact that these latter beds degenerate as they are traced across to the east side of the basin, while on the other hand, the underlying Main Limestone (Blackbyre) gradually assumes all the characters that in the Glasgow District are peculiar to the Hurlet Seam alone. In the Calderwood sections both seams are essentially of the same peculiar type, but further east only the Main Limestone retains these characters.

(5.) In addition to the previous record of *Pterinopecten papyraceus* from the Calderwood Cement, a further new occurrence of a Pendleside fauna has been observed in the Calderwood Glen section, below the Main Limestone (Blackbyre). Dr. Wheelton Hind has identified *P. papyraceus* and *Posidonomya becheri*, from this new horizon (*see* Palæontological Report, page 65).

(6.) The strata are abnormally thin on the west side of the basin, where an extensive overlap on to the Calciferous Sandstone lavas occurs, which diminishes rapidly to the eastward.

Carluke.—The revision of the Carboniferous Limestone and Calciferous Sandstone areas in this district was resumed by Mr. Hinxman, who found the faulted, undulatory structure, described in last year's Report, to continue southward in the direction of Lanark. Near Kilncadzow the Raesgill Ironstones occupy three contiguous, shallow, minor basins, in two of which they have been almost entirely worked out; in the third, at Bishopbent, a considerable area of ironstone must be present at no great depth from the surface.

The information at present available in the ground to the north-east of Carluke is sufficient for the general correlation of the principal horizons between the Index and the Main Limestone in the Carluke, Forth, and Wilsontown areas. The equivalents of the Index—the Climpy Limestone; of the Tower Coal—the Wilsontown Main Coal; and of the "Maggie Bands," Gas Coal, Raesgill Ironstones and Main Limestone and Coal, can be recognised with certainty in the Forth District. A closer correlation of the Upper and Lower Limestones and of the Calciferous Sandstone strata in these two areas, must await further opportunities of examining the results of recent boring operations.

While the close lithological resemblance of the Main Limestone and the immediately associated strata in the Carluke and Wilsontown areas to the Hurlet Seam of the Hurlet District is at once apparent, it is possible that they may occupy somewhat different stratigraphical positions. Evidence has recently been obtained in the ground to the west pointing to the occurrence of "Hurlet" conditions at two distinct horizons (*see* above).

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Coal Measures.

Polkemmet—Kirk of Shotts.—The revision of the Coal Measure area between Polkemmet and Salsburgh by Mr. Macgregor has yielded a good deal of new information regarding the position of coal-crops, faults, &c.

The seams worked in this area lie between the Airdrie Blackband and the Upper or Armadale Slatyband Ironstone. A summarised section of the metals is given below:—

	Fms.	Ft.	In.	Fms.	Ft.	In.
Airdrie Blackband Coal		—		0	1	8
Strata		—		11	3	0
Virtuewell or Benhar Coal	0	2	6 to	0	3	0
Strata	5	0	0 to	8½	0	0
Ladygrange Coal	0	0	10 to	0	1	8
Strata	9½	0	0 to	10½	0	0
Kiltongue Musselband		—		0	0	8
Strata	5	0	0 to	8	0	0
Kiltongue Coal, generally in two thin seams		—		0	1	3
Strata	12½	0	0 to	16	0	0
Upper Drumgray Coal		—		0	2	2
Strata	5½	0	0 to	10½	0	0
Shotts Laigh Coal	0	0	4 to	0	1	3
Strata	5	0	0 to	8	0	0
Lower Drumgray (Shotts Smithy) Coal		—		0	1	7
Strata	4½	0	0 to	5½	0	0
Shotts Gas Coal		—		0	1	6
Strata	11	0	0 to	15	0	0
Mill Coal		—		0	2	3
Strata	6½	0	0 to	10	0	0
Ball Coal		—		0	2	0
Strata	3	0	0 to	6	0	0
Main Coal		—		0	3	0
Strata	10½	0	0 to	14	0	0
Colinburn Coal		—		0	1	10
Strata		—		2	0	0
Armadale Slatyband Ironstone ...		—		0	0	8

The geological structure of the area is fairly simple, though complicated in the west by the intrusion of a number of abruptly transgressive sills of quartz dolerite. On the eastern margin the beds dip westward at low angles, while further west they are flat and rolling. The chief structural feature, not shown on the original map, is a 40-fathom fault, which has been proved to cross the ground for a distance of over five miles in a north-west-south-east direction. This fault forms the northern boundary of a trough, in which a wedge of Coal Measures, about half a mile in breadth, is let down amongst lower strata. It is worthy of remark that the dolerite sills which pierce the Coal Measures are associated in several collieries with anthracitic variation in coal seams which are normally bituminous. We are informed by the manager of the Barblues Colliery that at that pit the Upper Drumgray passes from a completely burnt coal—close to the intrusion—through good smokeless anthracite and steam coal into a house coal. In another colliery the Virtuewell Seam is anthracitic where near a sill.

Wishaw.—After completing his work in Sheet 31, Mr. Macgregor began the revision of the Coal Measures between Wishaw

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and Law Junction (Sheet 23). The coals worked in this area range from the Ell to the Lower Drumgray Seams. A fine natural section of the strata from below the Kiltongue to above the Ell is exposed in the Garrion Burn, the last mile of which has not yet been examined in detail. The section of the Kiltongue Musselband as seen in this stream is as follows:—

	Ft.	In.		Ft.	In.
Yellow Micaceous Sandstone.					
Oil shale		—		1	11
Musselband (*Anthracosia*)	0	4½	to	0	9
Blackband Ironstone		—	0 to	0	3
Dark blaes		—		1	4
Fireclay.					

Douglas Coalfield.—The re-mapping of the Douglas Coalfield has been continued by Dr. Crampton, who finds that the lowest beds in this basin—apart from a local development of Cementstones of Ballagan type—are lithologically of Upper Old Red Sandstone facies, and pass up, by intercalation of marine limestones, into strata of the Carboniferous Limestone Series in which the type of sedimentation is quite distinct. Remains of plants have been noted in the former strata, but the district has not yet been systematically searched for fossils, and the extent to which these rocks may be separated into Upper Old Red Sandstone and Calciferous Sandstone will mainly depend upon the palæontological evidence.

Three well-marked marine horizons underlie the workable coals of the middle group of the Carboniferous Limestone Series and may be tabulated as follows in descending order:—

(10.) Sandstones, shales, coals and ironstones, &c., of Carboniferous Limestones facies.
(9.) The MacDonald group of limestones, shales and ironstones, with Carboniferous Limestone forms.
(8.) Thin coal and fireclay.
(7.) Reddish-grey grits and mudstones, &c.
(6.) Hawthorn Limestone, with a marine fauna of Carboniferous Limestone type.
(5.) Thin coal and fireclay.
(4.) Reddish-grey grits, sandstones, mudstones.
(3) "Wee" Limestone, with marine Carboniferous Limestone fauna.
(2.) Thin coal and fireclay.
(1.) Grits, sandstones, marls, mudstones, cementstones and cornstones, of Calciferous Sandstone and Old Red Sandstone facies.

The marked change in the character of the deposits at the MacDonald Limestone horizon is brought out in the above table. The top of the Hawthorn Limestone, in all sections as yet examined, shows evidence either of exposure, or of a rapid shallowing of the waters, before the overlying strata were deposited. It forms a thin band with the appearance of a cornstone, containing fragments with fossils derived from the underlying limestone. This is overlain by mudstones with large polygonal mud-cracks, or by a massive grit with fragments of Silurian rocks,

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or locally with casts of Stigmarian stools *in situ*. This zone of subaerial deposits may be compared with similar zones which directly overlie the Coral Limestone of the Corrie section near Kilsyth, and the Coral Limestone of Aberlady, Dunbar and St. Monans in the East of Scotland. It would, however, be premature to attempt any direct correlation upon this evidence between such widely separated localities.

The workable coals between the Upper and Lower Limestones of the Carboniferous Limestone Series of the Douglas basin may be divided into four divisions as follows:—

On the Western side of the field at Bankend, Dalquhandy, Auchlochan and Bellfield.	On the Eastern side of the field: the Douglas and Ponfeigh District.
Gas Coal.	Nameless Coal.
Smithy and Dross Coals.	Drum Coals.
Ell Coal	Skaterig Coal
and associated strata 13 fms.	and associated strata 29 fms.
Black Band Ironstone position:—	
"Nine-feet" coal in two parts	Kirkrod Coal.
and associated strata 3 fms.	Stony Coal
	and associated strata 8 fms.

Horizon of Clayband Ironstone in black blaes with a central post of sandstone:—

About 7 fms.	About 14 fms.
"Six-feet" and "thirty-inch" coals and associated strata 7 fms	Back Seam.
	Rob Seam.
	Fallowhill and Coalypath Seams and associated strata 13 fms.

Thick strata of sandstone and some blaes:—

About 11 fms.	About 18 fms.
McDonald or Stinking Coal.	Sulphury and Wood Coals.

It is a reasonable assumption that the clayband horizon indicated in this table, beneath the Nine-feet seam, corresponds with the well-known "Black Metals" of the Kilsyth District and with the "Maggie Bands" of Carluke, Wilsontown and Bathgate. The approximate thickness of metals shown in the tables for either side of the field, brings out clearly the remarkable thinning of the strata that takes place from east to west in a distance of three miles. The numerous bore sections in the Douglas basin further demonstrate that the thickest development of the Carboniferous Limestone Series lies in the Douglas and Ponfeigh areas, and that a rapid thinning takes place to the N.W., W., and S.W., especially in the first direction. This change is accompanied by a thinning and partial disappearance of the coals in the northern part of the centre of the basin.

In the Upper Limestone Group the Castlecary, Calmy, Orchard, Lyoncross and Index Limestones can be recognised. Three coals have been worked in this group—the Gill Coal, representing the Hirst or Shirva Coal of Stirlingshire; the Gas Coal, beneath the Orchard Limestone; and the Ellenora Coal, on the same horizon as the Chapelgreen Coal of Kilsyth and the Lyoncross Coal of the Glasgow District.

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Economics.

Coal.—The three Crutherland coals in the East Kilbride area have all been wrought in past times round East Kilbride, but the upper seam is the only one now worked. It is a house coal of first-class quality, about 20 inches in thickness. A few small areas only of this seam are still available on the west side of the Rotten Calder, but further east, between Edge and Muirhouses, there are several square miles of unexploited ground in which all three coals should be found within 50 fathoms of the surface. There is unfortunately no reason to believe that the seams thicken in this direction.

On the north-east side of the 40-fathom fault which crosses the Harthill area east of Kirk of Shotts, the Main, Ball and Mill Seams are at present worked as steam coals of good quality. To the south-west of the fault, the Slatyband Ironstone, Upper Drumgray and Virtuewell Coals have been extensively wrought, but the other seams are still untouched over wide areas; the Ladygrange and Blackband Coals have also been raised to a small extent in two collieries. Thin clayband ironstones are associated with most of these seams, but have no value at present as a profitable source of iron.

The valuable Ell, Main and Splint Seams of the Wishaw District are now practically exhausted, though in a few small collieries the old stoops are at present being removed. The Kiltongue, Upper, Mid, and Lower Drumgrays are worked at Herdshill, and at Law Colliery, where the Virtuewell is also raised. In the latter field a thin "floating whin" occurs immediately above the Kiltongue Seam; the coal at the margin is burnt to a depth of 6 inches, and there is probably a large area over which the "clean" coal is too thin to be profitably worked.

Building Stone.—Freestone has been quarried for local building purposes at Eastfield, north-west of Fauldhouse. The section shows 50 feet of soft, yellowish, micaceous sandstone, with oval patches of very hard "kingle." The position is fixed by the presence, 12 feet above the sandstone, of the Kiltongue Musselband and Oil-shale. This quarry is at present disused, but may possibly be re-opened.

A soft freestone of fair quality is extensively quarried as a building stone at Hartfield, 2½ miles east of East Kilbride. Favourable conditions for working the stone are afforded by the flatness of the bedding, the thin cover, and the presence beneath the sandstone of a thin coal which is used in the engines.

Brick Clay.—At the Cleghorn Terra-cotta Brick Works, a red ferruginous clay, quarried 1½ miles W. by N. of Cleghorn Station, is used in the manufacture of salt-glazed, blue, "flashed" bricks and of red "terra-cotta" bricks, chimney cans, ridge and roof tiles. An analysis of the material, made by David Kirkcaldy & Sons, gives the following results:—

	Raw Clay.	Ignited Sample.
Silica	57·34	67·70
Alumina	18·81	20·90
Ferric Oxide	8·53	9·60
Lime	·63	·70
Magnesia	1·66	1·85
Water	9·65	—

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The rock in the quarry is a soft, more or less coherent clayey sandstone, but breaks down on exposure into a sandy clay. It occurs in seams several feet in thickness between beds of gritty sandstone; and in geological position probably lies near the junction of the Calciferous Sandstone with the Old Red Sandstone.

The 3-foot fireclay which underlies the Shotts Laigh or Mid Drumgray Coal at Herdshill Colliery, a mile north of Law Junction, is used for the manufacture, at Newmains, of fire-bricks and sanitary ware.

Limestone.—The Main Limestone, 10 feet thick, is worked at Thorntonhall, 2½ miles west of East Kilbride, in mines and open quarries, the product being of value as a flux in blast furnaces. Considerable areas of this seam could be raised from shallow pits; the most favourable locality is probably on each side of the railway between Limekilns and Murrayhill, where the bed lies almost flat at a depth of 10 to 15 fathoms.

III.—PETROGRAPHICAL WORK.

(1.) ENGLAND AND WALES.

Although field-work is no longer being carried on in South Wales, Cornwall or Devon, several Memoirs descriptive of the geology of parts of these districts were in preparation during the year 1910, and have received petrographical contributions from Dr. Flett and other members of the staff.

Mr. H. H. Thomas has made a special study of the volcanic rocks of Skomer Island, and Mr. Radley has prepared analyses to elucidate their chemical relationships. They comprise a varied assemblage of types ranging from felsites to olivine basalts. The striking peculiarity of the series is the abundance of rocks that are rich in soda. Soda-felsites, albite trachytes and keratophyres are numerous, consisting in large part of soda-felspar; with these there are mugearites which resemble those of Skye and the Lothians, and for certain types of intermediate composition Mr. Thomas has proposed the names skomerite and marloesite as they appear to have hitherto not been recognised in any other locality in England or abroad. The skomerites consist of albite felspar with augite; the marloesites of albite and augite with olivine.

Mr. Barrow and Mr. Dewey have prepared an account of the rocks of the Camelford and Padstow districts in Cornwall, which appears in the Memoir on that area published towards the close of 1910. Mr. Barrow describes the granite and the contact aureole; in the latter there is a great development of andalusite schists (sometimes containing chloritoid), and an exceptional abundance of rocks containing fresh cordierite. Mr. Dewey has ascertained the presence of pillow lavas resembling those of the Plymouth area, and of diabases and "proterobases" rich in albite; for the latter, which present many interesting peculiarities, he has proposed the name "minverite," after St. Minver, a locality at which they are abundant.

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Dr. Flett has written petrographical chapters for the Newton Abbot Memoir. This area contains an important development of Devonian and early Carboniferous volcanic rocks, in various stages of metamorphism (the Ashprington volcanic series). These are represented by pillow lavas (albite spilites) of the usual type in the west of England, and quartz-keratophyres. The association of keratophyres with spilites, so frequent in the palæozoic rocks of Britain, is here again exemplified; but the latter rocks, which consist of albite, quartz and a felsitic base, are found in this sheet only as tuffs and not as lava flows. These superficial volcanic rocks are accompanied by diabases, minverites and picrites, all of which (except the last) contain much albite. Where the rocks have been contact altered by the granite the felspar is changed to labradorite and andesine.

The investigation of the rocks of the Lizard (Sheet 359) has also been completed by Dr. Flett. In this area also there is a suite of pillow-lavas (spilites) of Veryan age, but they are not accompanied by keratophyres, though in the Mevagissey District that association again presents itself in the Veryan volcanic series. At Porthallow, however, intrusive rocks of the soda-felsite class have been injected into the pillow-lava group.

Around the banded Kennack gneisses and the acid intrusive rocks of the Lizard area some interesting pneumatolytic changes have been produced. The serpentine, for example, in contact with the acid rocks is often converted into aggregates of talc, tremolite and chlorite, which indicate the operation of vapours and solutions emanating from the granite. Probably connected with this we have a kind of alteration by which the acid rocks are " steatised "; their alkali-felspars are replaced by a waxy-looking aluminous serpentine or " pseudophite." The magnesia set free from the serpentine during the pneumatolytic process has replaced a large part of the alumina in the acid intrusive rock. The well-known " soap-rock " of the Lizard is a steatised granitic vein.

(2.) SCOTLAND.

Mr. H. B. Maufe, before his departure for Rhodesia, drafted an account of the volcanic rocks of the Glencoe District for the Memoir on Sheet 53. Mr. W. B. Wright, before joining the Irish Geological Survey, was engaged on the petrography of the Tertiary igneous rocks of Mull. Much time has been spent in correcting for the press the petrographical chapters in the Memoirs published during the year (Midlothian, East Lothian and Glenelg), and four other Memoirs not yet published.

In the Garve District of Ross-shire (Sheet 93) the metamorphic rocks of the Moine series of the North-eastern Highlands of Scotland occur in a condition that throws much light on their original nature and the manner in which they attained their present state. They are now mica-schists, quartzites, granulitic gneisses and zoisite hornblende granulites. During the survey the field evidence proved that these were sedimentary rocks because in places they retain their original bedding and pebbly

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structure, some of them being still recognisable as altered conglomerates. Microscopic and chemical investigation have supported this in the most satisfactory manner. It has been shown for example by analysis that these rocks have respectively the chemical composition of arenaceous shales, sandstones, arkoses (felspathic sandstones) and calcareous shales. With the aid of the microscope it is possible to follow every stage in the obliteration of their original clastic or sedimentary structures and the development of foliation and crystallization. The igneous rocks of the same area are gneisses, granulites and various types of hornblende and biotite schists, but analysis proves that they have the chemical composition of granites, aplites, basalts and lamprophyres. In this way conclusive evidence has been provided as to the original nature of the rocks that make up the Moine Series of this part of Scotland, and most important confirmation obtained of the views enunciated by Rosenbusch and other petrologists who hold that the chemical composition of metamorphic rocks is a valuable index to their original nature. Dr. Flett has prepared a full account of these rocks for the Memoir on the Garve area (Sheet 93) which is now in the press.

IV.—PALÆONTOLOGICAL WORK.

(1.) ENGLAND AND WALES.

Many of the fossils obtained during the course of geological mapping have been examined by Dr. Ivor Thomas, but reports have also been received from the following specialists, not members of the staff, to whom specimens from the Survey and Museum collections have been submitted:—Dr. F. A. Bather, Mr. S. S. Buckman, Miss Elles, Dr. Wheelton Hind, Dr. G. J. Hinde, Dr. R. Kidson, Mr. P. Lake, and Dr. C. A. Matley.

Dr. Thomas completed his revision of the genera of British Carboniferous Orthotetinæ, and this work has been published as a Memoir of the Geological Survey (Palæontology). Although his study was mainly confined to questions of generic classification and distribution, opportunity was taken to describe several new species; but the attempt was not made to deal exhaustively with all the known British forms, and the subject calls for still further investigation. It was found necessary to establish one new generic division, *Schellwienella*. It has been clearly shown that the arrangement of internal plates is of the greatest importance in generic allocation and that the phenomenon of external homœmorphy is so frequent in this sub-family as to prove most deceptive in attempts to determine specimens by the comparison of their outward characters alone.

Dr. Thomas has made further progress with his exhaustive study of the Carboniferous Productids of this country, and in order to advance this work he has spent some time in Scotland, examining materials in the collections of the Geological Survey and the Royal Scottish Museum in Edinburgh and the Kelvingrove and Hunterian Museums in Glasgow. He is indebted to the kindness of Messrs. John Smith of Dalry, R. Dunlop of

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Baillieston, and James Wright of Kirkcaldy, for facilities to examine their valuable private collections and for the offer of the loan of specimens. In connection with the work, field-sections were visited in the neighbourhood of Dalry and Kirkcaldy.

In order to enrich the Museum and to gather further materials for the investigation of the development and distribution of Carboniferous Anthozoa, Mr. J. Pringle has visited sections in Pembrokeshire and obtained a large number of zaphrentid corals. These mostly came from a horizon low in the series of beds designated C_2—S_1. They have now been placed in the hands of Mr. R. G. Carruthers, to whom they will prove of use in the detailed study of the Zaphrentidæ upon which he is engaged.

Dr. Kitchin has made a further examination of materials from deep-borings in Kent and Sussex, and has completed the present work on specimens from four of the localities. Amongst the fossils from the lower part of the Upper Kimmeridge Clay at Penshurst Boring were numerous little pyritised plates which for a time eluded attempts to identify them even generically.* In the belief that they might perhaps be the remnants of some pelagic crinoid, they were eventually submitted to Dr. Bather, who has recognised them to be the radial plates of a species (or possibly two species) of *Saccocoma*. This genus has not hitherto been known to occur in Britain, but in view of its abundance in the Solnhofen Limestone, of approximately the same age, its discovery in this country is of considerable interest and is not unlikely to prove of stratigraphical utility. A preliminary note on the specimens from Penshurst, contributed by Dr. Bather, is printed in Appendix II.

A set of specimens from the cores of the boring at Fredville, near Nonington, Kent, obtained by Mr. Lamplugh in a previous year, has been added to the reference-collection in the palæontological department. A preliminary examination of these core-samples has revealed some points of interest, particularly when the specimens illustrating the Jurassic sequence are brought into comparison with those from corresponding horizons at Dover and at Brabourne. The Hastings Beds here rest upon a series of impure limestones which have been referred provisionally to the Corallian System by Dr. M. Burr.† No Coral Rag, typically developed both at Dover and at Brabourne, was met with at Fredville, and it appears certain that the line of erosion falls in the Lower Corallian series. At a depth of 25 ft. below this line of unconformity the character of successive beds when traced downwards is seen to correspond with that of the lowest part of the Corallian Series at Brabourne. The agreement is precise, and is continued below the junction between the Oxford Clay and Corallian beds. Close correspondence is seen in the downward sequence of beds within the Oxford Clay when compared with the development observed to occur at Dover. The fossils met with at both localities in successive parts of the uppermost zone,

* *See also* 'Summary of Progress' for 1900 (*Mem. Geol. Surv.*), 1901, pp. 118, 119.

† M. Burr. 'The South-Eastern Coalfield,' *Science Progress*, No. 11, January, 1909.

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the Mariæ Beds, show the same sequence of occurrence, and the rocks of the lowest zone or Ornatus Beds exhibit identical features, both lithological and palæontological, at Fredville, Dover, and Brabourne. The underlying series of green and iron-shot beds, referred by Dr. Burr with doubt to the Kellaways Rock, may be definitely assigned to that formation. There is the closest lithological agreement, again, between beds occurring at a depth of about 1,287 ft. and a greenish grey claystone which at Dover has been ascribed to the Forest Marble. The evidence at present available to show the thickness of the Lias at Fredville is somewhat inconclusive, and leaves us uncertain whether the formation should be held to include less than 10 ft. or more than 20 ft. of the clays which here immediately overlie the Coal Measures. It may be noted, however, that the preliminary comparison between samples of rock containing *Rhynchonellæ* and belemnite-remains, met with at a depth of 1,363 ft., and specimens from Brabourne, strongly suggest that the Middle Lias has been reached at this depth, that is to say at a level 13 ft. above the junction with the Coal Measures.

An interesting suite of specimens obtained by Mr. Lamplugh in 1909 from a recent boring near Battle, Sussex, has not yet been thoroughly investigated but deserves a few words of mention. The boring, which was put down by the South Eastern Development Company, is situated nearly a mile N.N.E. of Battle Church and 2¾ miles E.S.E. from the old Sub-Wealden Boring. After passing through 345 ft. of Hastings Beds, 466 ft. of Purbeck Beds, and about 140 ft. of Portland Beds, the boring reached the Kimmeridge Clay at a depth of 952 ft. The Upper Kimmeridge Clay, which was found at Penshurst to exceed 600 ft. in thickness, is present in approximately the same development at Battle, and its lithological and palæontological characters are similar at these two localities. The Lower Kimmeridge Clay, or Virgula Beds, which was not reached in the boring at Penshurst, was found at Battle to consist in its upper part of sandstones with many decorticated examples of *Exogyra virgula* (Defr.). It is probable that nearly 500 ft. of strata should here be assigned to the Lower Kimmeridge Clay, so that this subdivision shows a striking increase in thickness when compared with its development as revealed by sections on the north side of the Weald. The few fossils obtained from the lowest levels reached have not yet been exhaustively compared, but it is probable that some inconsiderable thickness of Upper Corallian beds was penetrated.

Amongst the additions displayed on the palæontological galleries in the Museum attention may be drawn to specimens of *Fayolia crenulata* Moysey, and *F.* cf. *dentata* Ren. and Zeill., from the Middle Coal Measures of Derbyshire. These were described in the *Quart. Journ. Geol. Soc.*, vol. lxvi., p. 329, 1910, and have been presented by Dr. Moysey. The plants from the Forest Bed described by Mr. and Mrs. Clement Reid in the *Journ. Linn. Soc.*, Botany, vol. xxxviii., 1908, are mostly of small size, and in order that their form may be better understood the published illustrations of them have been mounted in a frame on the upper gallery. A series of plants from the clays of Bovey, in

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Devon, described by the same authors in the *Phil. Trans. Roy. Soc.*, B., vol. cci., p. 161, 1910, has been placed in the Museum, accompanied by photographs of the specimens.

Mr. Allen has carried out a considerable amount of revision and rearrangement among the Carboniferous, Jurassic, and Cretaceous fossils in the Museum. He has devoted a case to the separate exhibition of a number of zonal fossils from the Jurassic rocks, and a series of specimens to illustrate typical species from the successive zones is in course of preparation. Good progress has been made with the revision of ammonites in the Museum, and Mr. Buckman has named all those from the Lias.

The following specimens in the Museum have been figured and described during the year:—

IN THE PHIL. TRANS. OF THE ROYAL SOCIETY OF LONDON, SER. B., VOL. 201.

By MR. C. REID, F.R.S., and MRS. REID, B.Sc.

Calla *cf.* palustris *Linn.*, pl. xvi, figs. 50, 51.
Calvarinus reticulatus *C. and E. M. Reid*, pl. xv, figs. 18-20.
Cornus? pl. xv, figs. 7, 8.
Incerta sedes, pl. xvi, figs. 55-72.
Labiate, pl. xv, f. 21.
?Lezeunea minutissima *Hooker*, fig. 4, p. 174.
Magnolia attenuata *Weber*, pl. xv, figs. 1, 2.
Mastixia sp. nov., pl. xvi, figs. 73, 74.
Nyssa europaea *Unger*, pl. xv, f. 9.
,, obovata *Weber*, pl. xv, f. 10.
,, ornithobroma *Unger*, pl. xv, f. 11.
,, striolata *Heer*, p. 168.
,, vertumni *Unger*, pl. xv, f. 12; figs. 2, 3, p. 169.
Palmacites daemonorops (*Unger*), pl. xvi, figs. 44-49.
Potamogeton tenuicarpus *C. and E. M. Reid*, pl. xvi, figs. 53, 54.
Rubus microspermus *C. and E. M. Reid*, pl. xv, figs. 13-17.
Sagittaria? pl. xvi, f. 52.
Sequoia couttsiae *Heer*, pl. xv, figs. 23-27.
Taxodium distichum *Rich*, pl. xv, f. 22.
Taxus baccata *Linn.*, pl. xvi., figs. 42, 43.
Taxus? nitens (*Heer*), p. 172.
Vitis hookeri *Heer*, pl. xv, f. 3.
,, ludwigi *Braun*, pl. xv, f. 4.
,, teutonica *Braun*, pl. xv, figs. 5, 6.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY. VOL. LXVI.

By MR. L. MOYSEY, B.A., M.B., B.C.

Fayolia crenulata *Moysey*, pl. xxvi, figs. 2, 3; pl. xxvii, f. 1.
,, *cf.* dentata *R. and Z.*, pl. xxvii, f. 2.

IN THE MEMOIRS OF THE GEOL. SURVEY, PALÆONTOLOGY. VOL. I., PART 2.

By DR. IVOR THOMAS, B.Sc.

Orthotetes cantrilli *I. Thomas*, pl. xiii, figs. 5-8; f. 8, p. 117.
Derbyia gigantea *I. Thomas*, pl. xiii, f. 13; f. 10c, p. 121.

(2.) SCOTLAND.

The current Survey work of the year required the collecting of fossils from the Old Red Sandstone of Caithness, the Carboniferous areas of Central Scotland, the Mesozoic rocks of Mull and

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Morvern and the Cretaceous transported mass of Leavad, Caithness. The fishes, the plants, and the lamellibranchs have been named by Dr. Traquair, Dr. Kidston, and Dr. Wheelton Hind respectively. The other groups have been dealt with in the Survey Office.

As this year's palæontological work bears specially on stratigraphical questions and is closely linked with them, most of the details will be found in the reports of the field geologists.

Of special interest, however, is a series of fossils collected by Mr. Tait in the East Kilbride District, which fully corroborates the point first made out by Mr. Carruthers and mentioned in the "Summary of Progress" for 1909, page 47, namely, that a "Pendleside" fauna occurs there in the Calciferous Sandstone Series. The list of invertebrates given below confirms the statement that the fauna has a Pendleside facies, while on the other hand Dr. Kidston's determinations of the plants leave no doubt as to their Calciferous Sandstone age. The plants and invertebrates figuring in the appended lists are all derived from bands of shale and impure ironstone* occurring from 1 to 5 ft. above a seam of pyritous coal that lies 10 fathoms below the Main Limestone (or 21 fathoms below the seam correlated with the Hurlet Limestone). The principal species of invertebrates are as follows:—

Ambocoelia urei (*Flem.*)
Lingula mytiloides *J. Sow.*
,, squamiformis *Phill.*
Orbiculoidea nitida (*Phill.*)
Orthids
Productus *cf.* anthrax *Hind*
,, *cf.* corrugatus *M'Coy*
,, *aff.* latissimus *J. Sow.*
Posidonomya becheri *Bronn* [common]
Pterinopecten papyraceus (*J. Sow.*) [small specimens common]
Bucanopsis *cf.* marcouana (*Gein.*)
?Euphemus interlineatus (*Portl.*)
?Dimorphoceras discrepans (*Brown*)
?Glyphioceras truncatum (*Phill.*)
Nautiloid shell
Orthoceras sp.

Dr. Kidston has kindly furnished the following report:—

"The collection contained 72 specimens, but of these, some were too fragmentary or imperfect to admit of a satisfactory determination, though fortunately the greater majority of the fossils permitted of a specific identification.

This collection is remarkable for the large number of species obtained from a single Lower Carboniferous locality, as well as from the fact that they consist mainly of ferns or fern-like plants, the Lycopods being represented by few specimens, comprising only three species.

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* These belong to the lower of the two Calciferous Sandstone horizons mentioned by Mr. Carruthers in last year's Summary of Progress, page 47, as containing a Pendleside fauna. The upper bed has so far only yielded indeterminable fragments of goniatites, although the limestone is certainly of the peculiar Pendleside type.

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The following are the species contained in the collection:—

1. *Sphenopteris Schönknechti* Stur sp.
   1877. *Diplothmema Schönknechti* Stur. Culm Flora, Heft II, p. 140, pl. xiv, figs. 7-8.

This species is represented by one small fragment, but the pinnules agree perfectly with Stur's figure. It has not previously been recorded for Scotland. (T. 3252°.)

2. *Sphenopteris* n. sp.
3. *Rhodea moravica* Ett. sp.
   1865. *Trichomanes moravica*, Ett. Foss. Flora d. Mähr-Schles. Dachschiefers, p. 24, fig. 9, pl. vi, fig. 4.
   1875. *Rhodea moravica* Stur. Culm Flora, Heft I, p. 38, pl. x, figs. 3-7; pl. xi, fig. 1.
4. *Sphenopteridium crassum* L. and H. sp.
   1835. *Sphenopteris crassa*, L. and H. Fossil Flora, vol. ii, p. 21, pl. clx.
   1875. *Sphenopteris Kiowitzensis*, Stur. Culm Flora, Heft I, p. 32, pl. vi, fig. 8.
5. *Rhacopteris Lindseæformis* Bunbury sp.
   1861. *Adiantites Lindseæformis* Bunbury Geol. Survey of Gt. Brit. The Geology of the Neighbourhood of Edinburgh, pp. 144 and 151, fig. 26.
   1875. *Rhacopteris paniculata* Stur. Culm Flora, Heft I, p. 72, pl. viii, fig. 3.
6. *Rhacopteris Rœmeri* Feistmantel sp.
   1873. *Sphenopteris Rœmeri*, Feistmantel, Zeitsch d. deut. geol. Gesell., vol. xxv, p. 508, pl. xv, fig. 11.
7. *Rhacopteris flabellata* Tate sp.
   1853. *Sphenopteris flabellata* Tate in Johnston. Natural History of Eastern Borders, vol. i, Botany, p. 308, fig. 3.
   1889. *Rhacopteris flabellata*, Kidston. Trans. Roy. Soc. Edin., vol. xxxv, p. 422, pl. i, fig. 2; pl. ii, figs. 4, 5, 6 (non fig. 7).
8. *Adiantites antiquus* Ett. sp.
   1865. *Adiantum antiquum*, Ett. Foss. Flora d. Mähr-Schles. Dachschiefers, p. 22, fig. 7, pl. vii, fig. 1.
   1875. *Adiantides antiquus* Stur. Culm Flora, Heft I, p. 66, pl. xvi, figs. 4-6; pl. xvii, figs. 3, 4.
9. *Archaeopteris Tschermaki* Stur.
   1875. *Archaeopteris Tschermaki*, Stur. Culm Flora, Heft I, p. 57, pl. xii, fig. 1; pl. xvi, fig. 1.
   (Specimens Nos. T. 3201° and T. 3493°.)
10. *Archaeopteris Dawsoni* Stur.
   1875. *Archaeopteris Dawsoni*, Stur. Culm Flora, Heft I, p. 60, pl. xii, figs. 2, 2ᵇ, 3, 4, Heft II, p. 290, 1877.
   (Specimen No. T. 3221°.)

These last mentioned two species are very difficult to separate when in a fragmentary condition, but I believe both are included in this collection.

Archaeopteris Tschermaki is said to be distinguished from *A. Dawsoni* in its pinnules being entire and not possessing any notches or small blunt lobes and the veins are described as running almost parallel. In *Archaeopteris Dawsoni* the pinnules are broader and notched with blunt lobes and the less numerous veins radiate from the base of the pinnule.

These differences do not seem to be strictly limited to the individual species, for the pinnules of the upper part of *Archaeopteris Dawsoni* seem to be entire (Stur. Pl. xii., fig. 2ᵇ), while the lower pinnules of *Archaeopteris Tschermaki* appear to be sometimes notched (Stur. Pl. xii., fig. 1). The nervation of all the specimens I have seen from Scotland appears to radiate more or

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less from the base, and none could be described as possessing a parallel nervation.

11. *Telangium affine* L. and H. sp.
    1832. *Sphenopteris affinis* L. and H. Fossil Flora, vol. i, pl. xlv.
    1904. *Telangium affine*, Benson. Ann. of Botany, vol. xviii, p. 164, pl. xi, fig. 12; and text, fig. 33.
12. *Calymmatotheca bifida* L. and H. sp.
    1832. *Sphenopteris bifida*, L. and H. Fossil Botany, vol. i, pl. liii.
    1875. *Todea Lipoldi* Stur. Culm Flora, Heft I, p. 71, pl. xi, fig. 8; Heft II, p. 291.
    1887. *Calymmatotheca bifida* Kidston. Trans. Roy. Soc. Edin., vol. xxxiii, p. 140, pl. viii, figs. 1-5, 6[a]; pl. ix, figs. 16-17.
    1904. *Telangium bifidum* Benson. Ann. of Botany, vol. xviii, p. 164.
13. *Lepidophyllum lanceolatum* L. and H.
    1831. *Lepidophyllum lanceolatum* L. and H. Fossil Flora, vol. i, pl. vii, figs. 3-4.
14. *Lepidostrobus fimbriatus* Kidston.
    1883. *Lepidostrobus fimbriatus* Kidston. Trans. Roy. Soc. Edin., vol. xxx, p. 543, pl. xxxi, figs. 2-4.
15. Cf. *Bothrodendron* sp.

A small fragment of a branch, with sub-quadrate leaf scars, about 2 mm. wide and of the same height, with upper angle rounded. In the left-going spirals, the scars are about 1 mm. apart, but, in the right spirals, the leaf scars stand about 2 mm. distant from each other. The interfoliar cortex appears to be without any ornamentation. (Specimen No. T. 3261°.)

16. *Carpolithes-like seed.*

The already known British distribution of the fossil plants contained in this collection, is seen in the following table, and clearly shows that the rocks from which they were derived are of Calciferous Sandstone age.

	Carb. Limest. Series.	Calciferous Sand. Series.
1. *Sphenopteris Schönknechti* Stur.	—	—
2. ,, *n. sp.*	—	—
3. *Rhodea moravica* Ett. sp.	x	x
4. *Sphenopteridium crassum* L. and H. sp. ...	—	x
5. *Rhacopteris Lindseœformis* Bunbury sp. ...	?	x
6. ,, *Roemeri* Feistm. sp.	—	x
7. ,, *flabellata* Tate	?	x
8. *Adiantites antiquus* Ett. sp.	—	x
9. *Archœopteris Tschermaki* Stur.	x	x
10. ,, *Dawsoni* Stur.	—	—
11. *Telangium affine* L. and H. sp.	—	x
12. *Calymmatotheca bifida* L. and H. sp. ...	—	x
13. *Lepidophyllum lanceolatum* L. and H. sp. ...	x	x
14. *Lepidostrobus fimbriatus* Kidston	—	x
15. *Cf. Bothrodendron* sp.	—	—
16. *Carpolithes-like seed*	—	—

The species numbered 1, 2 and 10 have not been previously recorded from Britain."

Early in the season the services of Mr. Tait were lent to Mr. R. Campbell, of the Geological Department, Edinburgh University, who was then engaged in examining the stratigraphical relations of the rocks bordering the Highland Fault in the Stonehaven District, Kincardineshire. From a series of dark indurated shales (midway between Craigeven Bay and Garron Point, about ½ mile N.N.E. of Stonehaven Harbour) in

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which Dr. B. N. Peach had previously detected fragmentary remains attributable to some crustacean, Mr. Tait obtained a suite of specimens including at least two species of inarticulate brachiopods, together with numerous fragments of Crustacea belonging possibly to the Phyllocarida. The results of general interest brought out by this unexpected and important discovery are discussed by Mr. Campbell in a paper published in the Geological Magazine (February, 1911.)

V.—MUSEUM OF PRACTICAL GEOLOGY.

Temporary exhibits have been prepared by the field-officers to illustrate the areas described in the new Memoirs on the Melton Mowbray District (Sheet 142) and the one on the country around Padstow and Camelford (Sheets 335 and 336).

Amongst the acquisitions to the Museum may be mentioned the series of flint-implements from the gravel at Croxley Green, near Rickmansworth, Herts, presented by Sir Hugh Beevor, Bart.; a selection of economic minerals from Korea and Southern Manchuria, presented by the Japanese Commissioner for the Japan-British Exhibition; and the additions made to the collection of building-stones and road-stones from various sources.

In October the Curator attended the Committee of the International Association for the Testing of Materials, sitting in Holland and Berlin on the subject of the decay of Masonry. Numerous specimens were collected for the Museum and arrangements were made with Professor Dr. Hirschwald, of Berlin, for the presentation by him of a series of examples and photographs to illustrate his method of stone-testing as carried out in the laboratories at Charlottenburg.

The construction of a Relief-Model of the Ingleborough District by Mr. J. Foster Stackhouse has afforded an opportunity of adding another geological model to the series exhibited in the Museum. The model when purchased was plain, but geological information has been added in the Geological Survey Office under the superintendence of Dr. Strahan.

The horizontal scale of the model is 6 inches to 1 mile; the vertical scale is about $2\frac{2}{3}$ as great as the horizontal scale; an elevation of one inch on the model approximately represents 300 feet.

A Guide has been written for use with the model by Dr. Strahan; it contains two plates, one showing the uncoloured relief model while the other gives a geological map of the same region on the same scale. These plates are designed with a view to making it possible for the reader to follow the description given in the Guide apart from the model; it is hoped, therefore, that the Guide will be found useful to teachers and students of geology and geography. The price is fourpence.

List of Donations during the Year 1910.

H.R.H. Prince Albert of Wales.—A specimen of Flexible Sandstone (per Victoria and Albert Museum).

Barratt, W., Esq., F.G.S.—A specimen of *Homalonotus sp.* from the Lower Devonian of St. Eval, Cornwall.

Beevor, Sir Hugh, Bart., *M.D., F.R.C.P.*—A series of Flint Implements from the Gravel at Croxley Green, near Rickmansworth, Herts.

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BROUNGER, S. Y., ESQ.—Two specimens of Cassiterite from Northern Nigeria.

BURTON, W. H., ESQ.—A specimen of Gold and Silver Telluride Ore, Silver Stream Mines, Ltd., Maratoto, New Zealand.

CARD, G. W., ESQ.—Two specimens from Geffigong, New South Wales.

CHATTERTON, FRANK, ESQ.—A specimen of Silicified Wood from the Libyan Desert.

COLLINS, J. H., ESQ., F.G.S.—Three specimens of Stannite, from St. Agnes, Cornwall; a specimen of Cassiterite with Tourmaline from Wheal Kitty, Cornwall.

COMMISSIONER AT THE JAPAN-BRITISH EXHIBITION.—Specimens of Iron Ore, Copper Ore, Auriferous Quartz, Salt, Graphite, Coal, Galena, from Korea and from Southern Manchuria.

COOMBS, MISS A. K.—A tooth of *Cimolichthys?* from the Chalk.

CRONBACH, J. ESQ.—Several specimens of Autunite from Guarda, Portugal.

CROSS, J., ESQ., F.G.S.—Chalk Flints containing Foraminifera from Swanscombe, Kent.

DICKINSON, A., ESQ.—Several specimens of Rock Phosphate from Curaçoa, Dutch West Indies.

DIXON, E. E. L., ESQ., B.Sc., F.G.S.—Sixteen specimens of Rocks from Oregon and from Montreal, Canada.

DREW, MISS H., M.A., AND SLATER, MISS I. L., B.A.—Fourteen specimens of Rocks, and one hundred and thirteen specimens of Graptolites from near Llansawel, Carmarthenshire; in illustration of their paper read before the Geological Society of London, 13th April, 1910.

DREW, J. H., ESQ.—A series of polished specimens of inclusions in Granite and of Cornish Greenstones from the Collection of the late J. A. Phillips, Esq., F.R.S.

EVANS, E. E. J., ESQ.—A specimen of Barytes from the Pompren Mine, near Aberdaron, North Wales.

FLETT, J. S., ESQ., M.A., D.Sc., F.G.S.—A specimen of *Dipterus valenciennesi* Sedgw. and Murch. from the Old Red Sandstone of Achanarras Quarry, near Spittal, Caithness, N.B.

GENESI & Co., LTD., MESSRS. S.—A sample of Slate from North Italy.

GREEN, UPFIELD, ESQ., F.G.S.—Cone-in-Cone in Slate, Veryan Beds, Polurian Cove, Cornwall.

HALSE, E., ESQ.—Series of specimens from the Balcobo-Biariz Tin Mine, Province of Orensi, Spain.

HARGER, R. L., ESQ.—Implement of Serpentine from Mexico.

HASLUCK, F. W., ESQ.—Specimen of Terra Sigillata.

HERON-ALLEN, E., ESQ., F.L.S., F.R.M.S.—Three slides of Foraminifera and Ostracoda from Flint nodules in the Chalk of the Coranguinum Zone, at Swanscombe, Kent. Collected by J. Cross, Esq.

HOPKINS, E., ESQ.—A series of manufactured Rubies, Sapphires, and Spinels, in the rough and cut.

HORNE, DR. J.—*See* Peach.

HOUSTON, A. C., ESQ.—Two specimens of *Belemnites oweni* Pratt, and two vertebrae of *Ichthyosaurus sp.* from the Oxford Clay of Whittlesea, Peterborough.

HUDD, A. E., ESQ.—Nodule of Calcite and Iron Pyrites from Island Farm, East Molesey, Surrey.

JENKS, G., ESQ.—A scale of *Megalichthys sp.* from the Coal Measures of Coalbrookdale.

JOHNSTONE, MISS M.—Calcite, pseudomorphous, from Wadi Hof, Egypt.

KLOES, PROF. VANDER.—Samples of Trass.

LAMPLUGH, G. W., ESQ., F.R.S.—Eight specimens of Arizona rocks.

MARTIN, J. W., ESQ.—Three specimens, one carved, of Composition for preserving and restoring decayed stone.

MAWSON, PROF. D.—Specimens of Carnotite and radio-active Ilmenite from Radium Hill, near Olary, South Australia; three specimens of Chiastolite from Mount Howden, Bimbourie, South Australia; two specimens interglacial in Cambrian, Sturt River, South Australia; six specimens of Kenyite, slopes of Erebus, Antarctic.

MILBORN, MISS F. R.—Portion of a spine of *Hybodus sp. nov.* from the Oxford Clay of Peterborough.

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MILNE, SIR J.—Laurvigite Erratic, Aberdeen.
MITCHELL, R., ESQ.—Dressed block of Granite from Avochie Quarry, Aberdeen.
MOYSEY, DR. L., B.A., M.B., F.G.S.—Four specimens *Fayolia crenulata* Moysey, and two specimens *Fayolia* cf. *dentata* Renault and Zeiller, from the Middle Coal Measures (Top Hard Coal) of Shipley Clay Pit, Derbyshire.
NEELE, E., ESQ.—Samples of Dinorwic Slates.
O'DRISCOLL, FLORENCE, ESQ.—Specimen of Red Pumice.
PARKER, J., ESQ., M.A., F.G.S.—*Corbula sp.* from the Corbula Bed, Middle Purbeck of Durlston Bay.
PEACH, DR. B. N., F.R.S., and HORNE, DR. J., F.R.S., &c.—Fifty-seven micro-slides of rocks from the Shetland Islands, N.B.
PEARCE, DR. R.—Two specimens of Cassiterite from the Williams Shaft, Dolcoath, Camborne, Cornwall; and one specimen of Tin-ore from Monte Blance, Bolivia.
PETHERICK, H. R., ESQ.—Three samples of Coryton Slate.
PRESTON, HENRY, ESQ.—Specimen of Fibrous Gypsum, exhibiting curious notch, East Bridgeford, Nottinghamshire.
QUILTER, H. J., ESQ.—Nine micro-slides of Foraminiferal Limestone from Ireland and from India.
RASTALL, R. H., ESQ., M.A.—Ten rocks, Granite and contact-altered rocks around Skiddaw Granite.
REYNELL, A., ESQ.—Natrolite on Datolite from Parc Bean Cove, The Lizard, Cornwall.
ROBERTS, ADLARD, & CO., MESSRS.—Several samples of Foreign Slates.
RUMBOLD, W. R., ESQ.—Two specimens of Cassiterite with Bismuthinite from La Salvadora, Bolivia.
SCOTTISH GRANITE CO., LTD., MESSRS. THE.—Samples of "Silver-Grey" Granite.
SLATER, MISS I. L.—*See* Drew.
SPENCER, L. J., ESQ., M.A., F.G.S.—Alstonite with Witherite and Barytes: Witherite with Coal; Ullmannite with Galena; from the New Brancepeth Colliery, Durham.
STEBBING, W. P. D., ESQ.—Two specimens of *Nipadites umbonatus* Bowerb. from the London Clay, Isle of Sheppey.
STRAHAN, AUBREY, ESQ., Sc.D., F.R.S.—Four specimens of Magnetite with Apatite, and one specimen of the overlying Syenite, from Kiruna, Sweden; specimen of Tertiary Coal, Advent Bay, Spitzbergen; two Silurian Rocks, Aro, Sweden.
SULMAN, H. L., ESQ., F.I.C., M.I.M.M.—Specimen of White Zinc Blende, Broken Hill, New South Wales.
TARBUTT, PERCY C., ESQ.—Tarbuttite and Hopeite, Broken Hill, Rhodesia; Chrysotile Asbestos, Selukwe, Rhodesia.
TAYLOR, GEORGE, ESQ.—Samples of "Gatton" Stone, "Royal" Stone, and Fuller's Earth.
TEALL, DR. J. J. H., F.R.S., &c.—Four specimens of Flints, fractured by changes in temperature; from the desert between Mena House and Abu Roash, Egypt.
TULLY & CO., MESSRS.—Sample block of Green Mica.
UPTON, CHARLES, ESQ.—Slide containing *Chara laevigata* Upton, from the Forest Marble of Tarlton, Gloucestershire.
USSHER, W. A. E., ESQ., F.G.S.—Eight micro-slides of Devonshire Rocks.
VANSITTART, ARNOLD B., ESQ.—Hollow Flint containing a liquid from about 40 feet under the wall of the Water Works at Teddington; series of partially reconstructed Flint-flakes and cores.
VAUGHAN, S., ESQ.—Two specimens of Phosphatic Nodules from Weenen Town Lands, Weenen, Natal.
WALKER & CO., MESSRS, G. G.—Seventy-three specimens from the Transandine Tunnel, The Andes.
WARNER & CO., MESSRS.—Sample of Blue Brick and Brick-clay.
WELCH, R., ESQ.—Several samples of Peat impregnated with Dopplerite from Sloggan Bog, Randalstown, Co. Antrim.
YOUNG, E. A., ESQ.—Samples of Penrhyn Slates.
YOUNG, S. J., ESQ.—Coal showing "eenie" structure from Llay Hall Colliery, Cefn-y-Bedd, Denbighshire.

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VI.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year:—

(A.) ENGLAND AND WALES.

I.—MAPS.

(*a.*) *Four Miles to One-inch.*

New Series. Solid Edition.

Sheet 9 with 10 (Barmouth, Chester, Holyhead, Shrewsbury), price 2s. 6d.

Sheet 11 (Derby, Lincoln, Sheffield, Stafford), price 2s. 6d.

Sheet 13 with part of 17 (Fishguard, Haverfordwest, Milford), price 2s. 6d.

Sheet 15 (Birmingham, Northampton, Gloucester, Oxford, Worcester), price 2s. 6d.

(*b.*) *One-inch Maps (New Series).*

(Colour-printed, price 1s. 6d. each.)

Sheet 229, Carmarthen (Drift and Solid).
Sheet 335, Trevose Head (Drift).
Sheet 336, Camelford (Drift).
Nottingham District Sheet (Drift).

A colour-printed Drift Edition of the following sheets has been issued in place of the hand-coloured edition:—
Sheet 33 [Old Series 103 S.E.], Stockton.
Sheet 155, Atherstone.

(*c.*) *Six-inch Maps of Mining Districts.*

The undermentioned six-inch maps have been published with geological information (uncoloured, price 1s. 6d. each): coloured copies can also be obtained at an additional charge for colouring:—

Derbyshire, 40 N.W., N.E., S.W., S.E.; 41 N.W., S.W.; 45 N.W., N.E., S.W., S.E.; 46 N.W., S.W.; 50 N.W., N.E., S.W., S.E.
Nottinghamshire, 32 N.E., S.E.; 37 N.E., S.E.; 41 N.E., S.E.

(*d.*) *Six-inch Reference Maps.*

One hundred and eighty-eight MS. coloured copies of six-inch quarter sheets have been made from the field copies, and deposited in the Office for public reference. These are as follows:—

Carmarthenshire, 36 N.W. (part), 36 N.E., S.E.; 37 N.W.; 38 N.W.
Cornwall, 11 S.E. (part); 12 S.E. (part); 12a S.W. (part); 15 N.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W. (part); 22 N.W., N.E.; 23 S.E. (part).
Cumberland, 45 N.W., N.E., S.W., S.E.
Derbyshire, 12 N.W. (part), 12 N.E. (part), 12 S.E.; 13 N.W. (part), 13 S.W. (part); 18 N.W., N.E., S.E.; 19 N.W., N.E. (part) [Notts., 12 N.E.], 19 S.E. [Notts., 12 S.E.]; 20 N.W. (part) [Notts., 13 N.W.]; 24 N.E.; 26 N.E. [Notts. 17 N.E.], 26 S.E. [Notts., 17 S.E.]; 31 N.E. [Notts., 22 N.E.].

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Devonshire, 86 N.W. (part), 86 S.W. (part), 86 S.E. (part); 87 S.W., S.E.; 88 S.W., S.E.; 89 S.W., S.E.; 90 S.W., S.E.; 96 N.E. (part), 96 S.E. (part); 97 N.W., S.W., S.E.; 98 N.W., N.E., S.W., S.E.; 100 N.W., N.E., S.W., S.E.; 104 N.E. (part), 104 S.E. (part); 105 S.W. (part); 107 S.E.; 108 N.W., N.E., S.W.; 113 N.E.; 114 N.W.

Northumberland, 1 S.E.; 66a N.E., S.E.; 66 N.W., N.E., S.W., S.E.; 67 N.W., N.E., S.W., S.E.; 68 N.W., N.E., S.W., S.E.; 69 N.W., N.E., S.W., S.E.; 70 N.W., N.E., S.W., S.E.; 71 N.W., N.E., S.W., S.E.; 74 N.W., N.E., S.E.; 75 N.W., N.E., S.W., S.E.; 76 N.W., N.E., S.W., S.E.; 77 N.W., N.E., S.W., S.E.; 78 N.W., N.E., S.W., S.E.; 79 N.W., N.E., S.W., S.E.; 84 N.W., N.E., S.W., S.E.; 85 N.W., N.E., S.W., S.E.; 86 N.W., N.E., S.W., S.E.; 100 N.W., N.E., S.W., S.E.; 106a N.W., N.E., (106a S.W. with 106b N.W.); 106a S.E.; 106b N.E.

Nottinghamshire, 8 S.W. (part); 13 S.W. (part) [Derby, 20 S.W.], 13 S.E. (part); 14 S.W. (part), 14 S.E. (part); 15 S.W. (part), 15 S.E. (part) [Lincs., 59 S.E.]; 18 N.W., S.W.; 19 N.E., S.E.; 20 N.W., N.E. [Lincs., 68 N.E.], 20 S.W., S.E.

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APPENDIX I.

On a Deep Channel of Drift at Saham Toney, Norfolk.

By A. Strahan, Sc.D., F.R.S.

In August, 1910, a boring was commenced by Mr. J. Elwes Noble for the water-supply of Saham Hall. The site is about 150 feet above sea-level and 3 furlongs S.E. of a limekiln marked on the Old Series one-inch map 66 S.W., in which thin-bedded chalk with lines of nodular flints was visible to a depth of 25 feet in 1884.* Half a mile west of this another pit showed 35 feet of chalk, and half a mile to the east of it there is an old pit which has been evidently once worked for chalk. These three exposures formed the main evidence on which two areas of bare chalk were indicated on the map, at Saham Toney and to the west of it. The boring is situated near the southern margin of one of these areas, and it seemed likely that solid chalk would be reached at a small depth.

In November Mr. Noble reported that the following section had been met with.

Saham Hall.

	Thickness. Ft.	In.	Depth from Surface. Ft.	In.
Soil	1	6	1	6
Ballast	6	0	7	6
Gravel and sand	10	6	18	0
Grey sand	14	0	32	0
Clay	2	6	34	6
Chalk and clay	126	6	161	0
Grey sand	11	0	172	0
Clay and chalk	36	4	208	4
"Chalk" [Boulder Clay]	39	8	248	0

Specimens of the "Chalk and clay" from a depth of 160 feet and of the "Grey sand" from a depth of 167 feet were sent to this Office for examination. The former proved to be Boulder Clay with boulders of chalk, while the latter contained small veins of clay with pellets of chalk, and evidently also formed part of the Glacial Deposits.

Subsequently a specimen of the "Clay and chalk" from a depth of 198 feet was examined by Mr. Reid and found to be composed partly of soft Upper Chalk but to contain a number of pellets of hard chalk (perhaps Middle Chalk), splinters of flint, a fragment of earthy limestone, and much grey sandy marl. Finally a specimen of the "Chalk" from the bottom of the boring at a depth of 248 feet proved to be Boulder Clay. The Chalk therefore was not reached and the total depth of Drift is still unknown.

In 1898 a boring was made by Messrs. Adcock at Broomley Hall, 6½ furlongs east of Saham Hall and about 120 feet above

* The Country around Attleborough, &c. (*Mem. Geol. Surv.*), 1884, p. 3.

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sea-level. The section, which was communicated by Mr. F. W. Harmer and was published in the Memoir on "The Geology of the Borders of the Wash," 1899, p. 134, was stated to have been as below:—

Broomley Hall.

		Thickness. Feet.	Depth from Surface. Feet.
Glacial gravel		20	20
Boulder Clay.	Blue clay	80	100
	Hard flints with clay	10	110
	Chalk and chalk-marl	2	112
	Clay	35	147
Chalk		—	—

In 1905 a boring was made by Messrs. Isler & Co. at Broomhill Farm, 15 furlongs south-east of Broomley Hall and about 160 feet above sea-level. The following description of the strata traversed and of the water obtained has been furnished by Messrs. Isler & Co.

Broom Hill, Watton.

	Thickness. Feet.	Depth from Surface. Feet.
Mould	3	3
Sand and ballast	4	7
Ballast	8	15
Loam	5	20
Blue silt	65	85
Fine grey sand	30	115
Conglomerate	6	121
Fine grey sand	16	137
Conglomerate	4	141
Fine grey sand	10	151
Chalk and flints	155	306

A water-supply of 500 or 600 gallons per hour was obtained but it was charged with iron.

Lastly, Mr. Noble states that a well was dug to a depth of 42 feet, 500 yards north-east of Saham Hall. The well, as he was informed, yielded a very fair supply from the Chalk, but evidently too much reliance must not be placed on the distinction of chalk from chalky boulder-clay by the workmen. Apart from the evidence afforded by this well, however, the chalk-pits previously mentioned leave us in no doubt that the Chalk comes to the surface both to the west and to the north of Saham Hall, and that it reaches an elevation of 160 to 180 feet above the sea. At Saham Hall and Broomley Hall on the other hand the chalk-surface is 98 feet or more and 27 feet respectively below sea-level, while at Broomhill Farm it is about 9 feet above sea-level.

The evidence does not suffice to enable us to trace the shape or direction of this hollow, but it may be assumed that it is probably a buried channel similar to those which have been found in various parts of the east of England.

Comparison may be made with some Suffolk borings.* At Brettenham Park the drift was 312 feet thick and extended to

* The Water Supply of Suffolk (*Mem. Geol. Surv.*), 1906, p. 8, &c.

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about 32 feet below sea-level; at Euston it was 224 feet thick and extended to about 144 feet below sea-level; at Glemsford it was 470 feet thick and extended to 347 feet below sea-level.

Ipswich is underlain by one of these drift-filled channels extending to about 100 feet below sea-level, and in the northern inland part of Essex a similar channel has been traced, though of course not continuously, for some 11 miles along the valley of the Cam, and at one place to a depth of nearly 140 feet below sea-level.* Another near Hitchin has been traced for about 7 miles, and proved at one point to extend 68 feet below sea-level.†

The following additional information has been supplied by Mr. Noble while this volume is passing through the press. The Saham Hall boring was abandoned at 249 feet and a second boring was made 200 yards further to the west-north-west, at a spot selected by a diviner. The height above O.D. at the second boring is approximately 145 feet. Chalk was reached at a depth of 17 feet under ballast, clay and sand, and was bored into for 244 feet. The supply of water was proved to exceed 1,000 gallons per hour.

The Chalk surface at the site of the second boring is about 128 feet above O.D., whereas at the first boring it is more than 98 feet below that datum. Its slope therefore has a gradient of not less than 1 in 2·6, and is possibly much steeper.

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* W. Whitaker, *Quart. Journ. Geol. Soc.*, vol. xlvi., 1890, p. 333.
† W. Hill, *Quart. Journ. Geol. Soc.*, vol. lxiv., 1908, p. 8.

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APPENDIX II.

Note on Crinoid Plates from the Penshurst Boring.

By Dr. F. A. Bather, F.R.S.

At the Penshurst boring the cores from depths of 1,794 to 1,807 feet, in a hard grey shale assigned to the lower part of the Upper Kimmeridge Clay, contain fairly numerous thin pyritised bodies, roughly scutiform, and with a punctate surface. Dr. Kitchin, having formed the opinion that they might be plates of a crinoid, very kindly submitted them to me, and after some hesitation, due to the unusual mode of preservation, I was able to endorse his opinion. The specimens are, in fact, the radial plates of the crinoid *Saccocoma*. The pyritised plates themselves are as a rule seen from within, but the impressions of others on the shale enable us to reconstruct the appearance of the outer surface. The body of each plate is shield-shaped, with sides gently curving towards the slightly rounded basal end. The upper margin of the shield is produced upwards into processes so thin that their outline has been rendered indefinite: their inter-radial margins appear, however, to continue the outline of the sides of the shield, and their adradrial margins appear to pass downwards obliquely from the interradial margins towards the perradius, thus enclosing a V, at the apex of which may have been the radial facet. In the median line (perradius) of the shield, as viewed from the inner face, is a ridge, which forks below into branches diverging very slightly; each of these branches soon after its origin unites with a ridge descending from the middle of the process on that side; these latter ridges thus enclose a triangular space. This space, both within the shield and in its extensions on the processes, is irregularly perforate. The lateral areas of the shield are marked with longitudinal ridges concentric with the outer curved margins, and with transverse ridges connecting the same at regular intervals. Sometimes the longitudinal system is the more prominent, sometimes the transverse system; but the appearances vary greatly with the direction of the lighting. The depressions between the crossing ridges may be simple punctæ, or may have been sometimes perforate. This kind of ornament appears to have continued upwards on the outer region of each process.

The preceding description applies to all the objects. There are, however, considerable differences in the size and regularity of the perforations and punctæ; and there is some indication that these may be correlated with the proportions of the plates. There seems in fact to be a relatively broader form with larger, and often less regular, ornament (3472b and c), and a longer, narrower form with finer and more regular ornament (3498a). Should this correlation be confirmed by further study, it will be held to indicate the existence of two species. The samples of core are numbered 3471-3476 and 3491-3501. Various specimens on each core are here further denoted by letters of the alphabet.

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The principal measurements, in millimetres, of three selected examples are:—

	3472b	3472c	3498a
Total extreme length	3·6	2·8	—
Length of shield	2·3	1·8	3·5
Greatest width	1·6	1·4	2·1
Ratio, width : length	·69	·77	·6
Number of ridges down one-half	5	3	8

Specimens which, so far as their weathered condition allows one to judge, were similar in structure and in mode of preservation, were detected by Mr. G. W. Lamplugh in a transported slab of Kimmeridge Clay occurring in the Ferruginous Sands at Little Stairs Point, Isle of Wight (*see* "Summary of Progress" for 1900, pp. 118, 119; 1901).

The genus *Saccocoma* has not hitherto been recorded from Great Britain, but its discovery at this horizon is not more than one might expect, since it is represented by swarms of individuals in the approximately contemporaneous lithographic stone of Solnhofen, and since, as a free-swimming form, it was ready to avail itself of any favourable opportunity for rapid migration. The species, it is true, do not appear to be the same as those already known from Bavaria. But, since at least two species are found associated in the lithographic stone, and since two rather widely dissimilar forms occur in these cores, we may suppose that *Saccocoma* was either in a state of rapid evolutionary change, or was prepared to adapt itself quickly to slight differences of environment.

A detailed description of these very interesting fossils, with adequate illustrations, is in active preparation. Meanwhile the attention of collectors is directed to them, since, now that their existence is known, they may the more readily be detected in the Kimmeridge Clay of other localities. It would be of particular value if remains of the curiously expanded brachials possessed by *Saccocoma* could be found in contact, or even in a less close association, with these radials.

24th September, 1910.

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APPENDIX III.

On the Occurrence of a Cretaceous Boulder of unusual size, at Leavad, in Caithness.

By R. G. Carruthers.

During the course of field work in Caithness in 1907, a sand pit was noted in the heart of the county, at Leavad, about three miles south of Spital. The pit is situated on the easterly slopes of Strath Beg, about fifty feet above the Little River (a tributary of the River Thurso), and is from 10 to 20 feet deep.

An examination of the section showed that the sand, which had a thin covering of boulder clay, was not of glacial or alluvial origin, but had resulted from the extensive weathering of a calcareous sandstone, remarkably homogenous in texture. Remnants of this sandstone were seen as curious mammillated bosses, left behind after excavation of the sand, which is used as an abrasive in cutting flagstones at the Spital quarries.

Calcareous sandstones of somewhat similar type (although with more or less clearly marked bedding planes) are common in the Old Red Sandstone of the district, and in the absence of further evidence, it is probable that the Leavad sand would have been regarded as an unusually decomposed representative of such strata. But an entirely different complexion was put on the matter through the discovery, in 1908, by Mr. Tait, of fragmentary fossils in the bosses of undecomposed sandstone.

Dr. Lee thought that the assemblage had a Cretaceous aspect, and eventually reported as follows (*see* "Summary of Progress" for 1908, page 75):—

"These fossils include Lamellibranchs, Gasteropods, and Cephalopods, only a few being specifically determinable on account of the coarse nature of the matrix. The better preserved specimens were submitted to Dr. F. L. Kitchin, who determined them as follows:—

Pecten (Syncyclonema) orbicularis *J. Sow.*
Pteria (Oxytoma) sp.
Desmoceras?
Craspedites sp. (probably sp. nov.)
Hamites sp.
Crioceras sp. (1) (fragment illustrating a simply costate stage).
Crioceras sp. (2) (fragment illustrating a spinous stage).

"Dr. Kitchin remarks that the fossils are of Cretaceous age and that the assemblage, taken as a whole, points to a Lower Cretaceous rather than an Upper Cretaceous horizon. He also thinks it probable that they are either Valanginian or Hauterivian, that is, from a lower horizon than those from Moreseat, which were believed by Mr. Jukes-Browne to be of Aptian age."

The extreme interest of this discovery is obvious when it is remembered that Cretaceous rocks are very rare in Scotland, and that the nearest exposure to Leavad of such strata is at Moreseat, in Aberdeenshire, about a hundred miles to the south-east. It was very desirable, therefore, to ascertain whether the Leavad mass was *in situ*, or transported. Against the former view was the general nature of the field evidence, and also the important fact, to which attention was drawn by Dr. Horne, that no Lower

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Cretaceous transgression on to Palæozoic rocks was known in north-west Europe. On the other hand, the great size of the mass (the quarry alone is 160 yards long) made it difficult to accept the transportation theory without reserve.

A careful examination of the ground showed that a definite solution of the problem could only be obtained by boring. An application was therefore made by Dr. Horne to the Council of the Royal Society and a grant was obtained to enable bores to be put down, and this work was satisfactorily executed in July and August of last year (1910). The bores were made by a long iron tube, 3 inches in diameter, and having a valve at the lower end, so that good samples could be obtained of the strata passed through. Hard gravel or large stones were pierced with a chisel, and the sides of the bore were tubed, to prevent choking.

Ten bores in all were put down, their disposition being shown on the accompanying sketch map (Fig. 6).

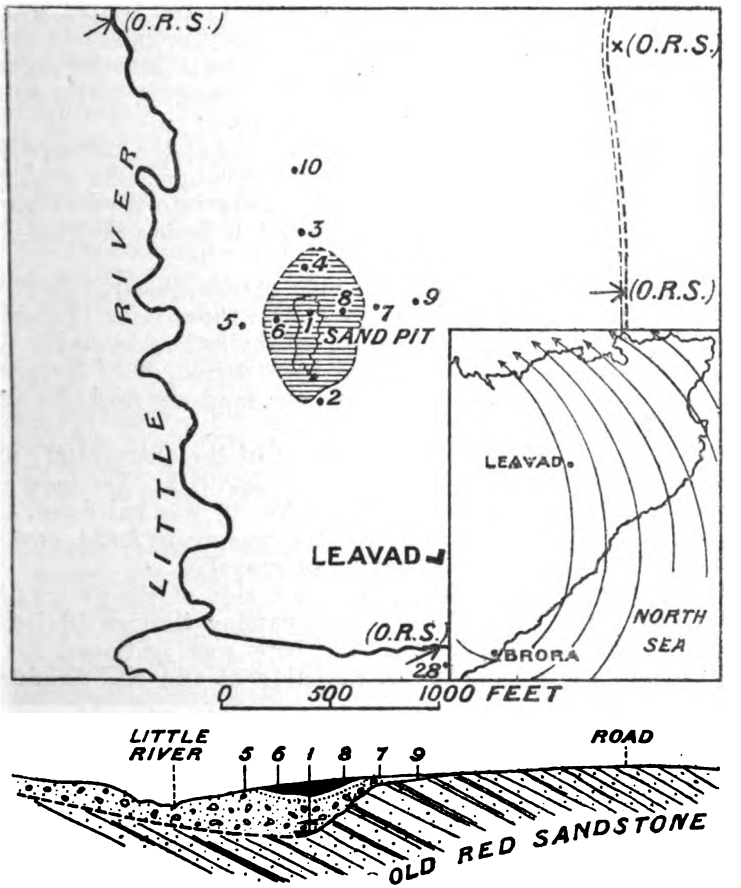

Fig. 6. Diagram illustrating the mode of occurrence of the Leavad Boulder. The area of sandstone is indicated by horizontal lines. The bores are numbered.

The inset is an outline map of Caithness showing direction of glaciation.

The horizontal section is taken in an east and west direction through the sand pit. Sandstone in black, with boulder clay underneath. Vertical scale = twice horizontal.

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The chief bore, No. 1, was put down at the northern end of the sand pit itself, and carried to a depth of 79 feet. In this bore, after passing through nine feet of the sand worked in the pit, a bed of dark green clay was met with, somewhat micaceous, and containing foraminifera, iridescent shell fragments and some small pellets of iron pyrites. There were distinct planes of bedding, although it was impossible to ascertain whether they were disturbed or not. This green clay, alternating with more sandy layers, proved to be 11 feet 6 inches in thickness. The bore then passed into a typical shelly boulder clay, with well-striated pebbles of schist and granite, together with others of Old Red Sandstone, local in origin. With some slight alterations in colour, and the intercalation of three beds of gravel, this boulder clay continued for the remainder of the bore, the total thickness of boulder clay and gravel passed through being 59 feet 5 inches.

It was evident, therefore, that the sand in the Leavad quarry belonged to a transported block, and it only remained to determine the approximate dimensions of the mass. For this purpose shallow bores were put down along lines ranging north, south, east and west from No. 1 Bore (*see* Fig. 6).

No. 2 Bore was put down at the south end of the quarry, a few yards outside the limit of the old sand workings. No sand was found, the bore passing almost immediately into the dark green shelly clay, which proved to be 25 feet 6 inches thick at this point and rested upon boulder clay.

No. 3 Bore was on the north side of the quarry, 100 yards north of No. 1. No sand was met with, there being 11 feet of green foraminiferal clay, underlain by shelly boulder clay. The northern limit of the sand having been passed, No. 4 Bore was put down 50 yards nearer No. 1, and the sand was reached underneath 8 feet of moss and boulder clay.

No. 5 Bore was put down to the west of the quarry, 100 yards west of No. 1; boulder clay only was met with. The bore was stopped 10 feet down, and another (No. 6) was put down, and 50 yards nearer No. 1. Here the sand was again found, covered by 9 feet of moss, and dirty sand and gravel

No. 7 Bore was situated on the east side of the quarry, 100 yards east from No. 1 Bore. After passing through 10 feet of moss, brown clay and gravel, the bore was continued 2 feet further into broken sandstone, probably of Old Red Sandstone age.

No. 8 Bore was then put down 50 yards nearer No. 1 and the sand was again reached underneath 3 feet of moss and boulder clay.

As it was possible that the "broken sandstone" found in No. 7 Bore might be an unweathered portion of the Cretaceous mass, another bore (No. 9) was put down 150 yards east from No. 1, but broken sandstone was again met with under 2 feet of moss and boulder clay. It is, therefore, highly probable that both No. 7 and No. 9 Bores reached the bed rock of Old Red Sandstone, which is seen outcropping to the east in a quarry by the roadside, and in stream sections to the south and north-west (*see* Fig. 6).

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As a small exposure of the Leavad sand is seen in the stream at Tasker, about half a mile north of the quarry, a final bore (No. 10) was put down 200 yards north of No. 1, to ascertain whether any considerable mass of sand existed in this direction. No sand was met with, however, the green foraminiferal clay, 5 feet 6 inches thick and underlain by boulder clay, being found under 1 foot 6 inches of moss.

The shells in the green clay from Bore No. 1 and Bore No. 2 were in remarkably fresh preservation and apparently unfossilised. Foraminifera were abundant, but whole specimens of other forms were rare, most of the material being in a highly comminuted condition, possibly from the percussive action of the boring tube. The organisms occurred in distinct layers. Dr. Lee examined the material, and has drawn up the following list:—

Shells from green clay under Leavad Boulder—

1. *Truncatulina praecincta* (Karrer). This is the predominant form, described from the Miocene of the Banat, and common in the Miocene and Pliocene of Italy. Recorded by Brady from the coral reefs of the tropics, 15-255 fathoms. Not recorded from Britain.
2. *Truncatulina sp.*
3. *Rotalia soldani* d'Orb. Oligocene—Recent, cosmopolitan species.
4. *?Cristellaria sp.*
5. *Nonionina asterizans* (Ficht. and Moll) Tertiary—Recent, cosmopolitan.
6. *Nonionina scapha* (Ficht. and Moll) Miocene—Recent, cosmopolitan; also:

Fragment of Brachiopod.
Nuculana sp.
Gasteropod.
Glacially striated Belemnite (found near the top of the clay in No. 2 Bore).

The brachiopod, *Nuculana*, and gasteropod, were submitted, through Dr. Kitchin, to Mr. Henry Woods. Mr. Woods did not recognise them as Cretaceous forms, but, while suggesting that they might be of any later date up to Glacial, could not fix their age.

Dr. Lee's determinations of the foraminifera are especially interesting; he remarks that "the general assemblage is decidedly post-Cretaceous in aspect, but differs in many respects from that found in the shelly boulder clay of Caithness. For instance, the commonest form at Leavad, *Truncatulina præcincta*, has not been recorded at all from the Caithness boulder clay. Its occurrence in the Italian Tertiaries and the coral reefs of the Pacific suggests that the Leavad clay may belong to some part of the Crag." The clay can hardly be interglacial, because, apart from other lines of argument, the shelly boulder clay of Caithness is not found in two divisions; occasional small lenticles of clay or sand, may be found, but they do not resemble the Leavad clay, while they do not form a continuous bed, their distribution being quite sporadic.

It seems clear at any rate that the green clay is of post-Cretaceous age and was not an original component of the sandstone block; the clay and sandstone, although they are now in intimate conjunction, must have come from different sources.

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The processes by means of which this great complex mass was brought to Leavad are no doubt obscure, and more data are required before a satisfactory theory can be elaborated: possibly the sequence of events may have been somewhat as follows:—

As the great ice sheet, which finally crossed Caithness, advanced over the bed of the North Sea,* a great mass of green clay, forming a part of the sea bottom, was torn up; during this process there was some incorporation of foreign material, as instanced by the discovery of a glacially striated belemnite in the upper part of the clay. The underlying Neocomian sandstone thereby laid bare, was then also broken up by the ice sheet, and pushed over the clay, the whole being subsequently frozen solid and transported *en masse* to Leavad.

This enormous lens-chaped block was naturally not carried so far without fracture and disintegration. The sand in the pit is traversed by several deep vertical cracks, filled with boulder clay, and narrowing downwards, while small isolated masses of the decomposed sandstone can be seen embedded in boulder clay, in the stream sections north and west of the pit. The decalcification of the sandstone has been so complete that the greater part is now in the condition of soft sand, giving rise to no feature whatever on the surface of the ground; the original mass may well have been much thicker than that now found.

Conclusion.

The investigations have shown that:—

(1.) The Neocomian sandstone of Leavad is part of a glacially transported mass of complex composition, and of very large size. The lower part of this boulder consists of a green foraminiferal clay, of post Cretaceous age. The sandstone portion is approximately 240 yards long, 150 yards broad and about 26 feet thick. The underlying green clay extends at least 120 yards further to the north, and at one spot was found to be 25½ feet thick.

(2.) The Neocomian age of the sandstone suggests that the coastal belt of Jurassic rocks at Brora is succeeded, a short distance out to sea, by a normal sequence of Cretaceous rocks,† there being little or no transgression of the Upper Cretaceous in this region.

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* It should be remembered that the greater part of Caithness is covered with shelly boulder clay, and it has long been an accepted opinion amongst glacialists that the boulder clay was brought by a glacier coming from the North Sea, and moving over the country in a general north-westerly direction. A full account of this matter has been given by Messrs. Peach and Horne. *Proc. Roy. Phys. Soc. Edin.*, vol. vii. (1881), p. 316.

† The presence of Upper Cretaceous strata over some part of the sea bottom south-east of Caithness has long been evident from the abundance of flints and Upper Cretaceous fossils in the shelly boulder clay covering the eastern part of the county.

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OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1911.

I.—*INTRODUCTION.*

By J. J. H. Teall, M.A., Sc.D., F.R.S., Director.

The work of the Geological Survey in England and Wales during 1911 was continued on the same lines and in the same districts as in the previous year. These districts may be referred to as (1) the Denbighshire District, (2) the Warwickshire and South Staffordshire District, and (3) the London and South-eastern District.

In the Denbighshire District the work is directed to the completion of the primary six-inch survey of the areas represented by the New Series One-inch Ordnance Maps in which the coalfields occur. The work, therefore, necessarily extends on the east into areas occupied by rocks newer than the Coal Measures, and on the west across the outcrops of the Lower Carboniferous rocks into the Silurian and Ordovician regions.

In the Warwickshire and South Staffordshire District work is proceeding not only in the coalfields, but also in the intervening tracts, where the productive measures are covered by a variable thickness—sometimes very great—of unproductive Coal Measures and rocks which may be collectively referred to as belonging to the New Red Sandstone formation. The re-survey of this region, so far as it has gone, has not resulted in the separation from the Coal Measures on the one side, or the Triassic rocks on the other, of any deposits to which the term Permian can with confidence be applied, but the critical regions in which evidence on this important question may be expected to be found have not yet been re-surveyed.

In the London and South-eastern District work has been continued on both sides of the Thames in the counties of Berkshire, Buckinghamshire, Surrey, Hertfordshire, and Middlesex. The well-known subdivisions of the Chalk and overlying Tertiary strata are being traced in detail, together with the various gravels, sands, loams and brickearths, which constitute the Superficial Deposits. While the mapping of the Chalk has an important bearing on questions of deep-seated water supply, that of the Tertiary and Superficial Deposits has a special bearing on matters relating to

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agriculture, horticulture and sanitation, apart from the economic uses to which the gravels, sands and brickearths are put.

In Scotland the work of mapping for the first time the igneous and metamorphic rocks of the Highlands and Western Islands has been continued in the Island of Mull and in parts of Sutherlandshire, Perthshire, Inverness-shire, and Argyllshire, while the revision of the Carboniferous areas has been carried on in Lanarkshire and Ayrshire. The revision of the Lanarkshire Coalfield is approaching completion. The preparation of a new edition of the Memoir on the Oil Shales of the Lothians has necessitated a revision of the oil-shale fields. This revision, following on a period of extraordinary activity in boring, has proved of value in bringing forward new means of determining the positions of the most important ' shales ' in bores and shafts, and has indicated the existence of areas in which the search for oil-shale is likely to prove successful in the immediate future.

Brief references to the various geological formations taken in chronological order will now be made.

PRE-CAMBRIAN ROCKS AND CRYSTALLINE SCHISTS.

Crystalline schists have been surveyed in the south-eastern portion of the Morvern peninsula, Argyllshire, where they have been found to be invaded by an extensive mass of granite associated with pegmatites. Gneissic inclusions are sometimes abundant near the margin of the granite mass, and in one district the foliation in these apparently detached inclusions possesses a common strike agreeing with that in the surrounding schists.

Another district in which crystalline schists associated with later igneous intrusions has been surveyed lies in East Sutherland. Here the main work of the surveyors, apart from the delimitation of distinct intrusions and special bands in the gneissose complex, consists in separating areas of the so-called Lewisian type from others of Moine type. Although it is not difficult to trace the boundary line its precise significance is not yet clearly understood. Both areas have been much affected by granitic and pegmatitic intrusions.

LOWER PALÆOZOIC ROCKS.

Portions of the old ridge of lower Palæozoic rocks on which the Coal Measures of Central England were deposited, have been surveyed during the year. They include the small inlier of Cambrian rocks at Dost hill, on the western margin of the Warwickshire Coalfield, and the larger inlier of Silurian rocks on the eastern side of the South Staffordshire Coalfield. In the latter case the subdivisions recognised by previous observers have been delimited on the six-inch maps.

Reference has already been made to the fact that the completion of the area represented by the one-inch maps, in which the Denbighshire and Flintshire Coalfields are situated, will necessitate the survey of considerable tracts of Lower Palæozoic rocks which lie to the west of the Carboniferous districts. This work has been commenced. Small tracts of Ordovician rocks have been mapped in Glyn Ceiriog and on the high ground to the north of the Vale of

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Llangollen. The Silurian area to the south of the Vale of Llangollen has also been partially surveyed, and a definite succession in this monotonous series of beds has been established in which two graptolitic horizons—one characteristic of the Lower Ludlow and the other of the base of the Wenlock—have been recognised.

CARBONIFEROUS.

Carboniferous Limestone has been surveyed on the western margin of the Denbighshire Coalfield in the neighbourhood of Llangollen. The celebrated section exposed in the escarpment of the Eglwseg rocks, so well described by the late Mr. G. H. Morton and others, has been studied in the light of recent discoveries as to the succession of life-zones in this formation. In the same district a series of sandstones, grits and shales, referable to the Millstone Grit group, has been delimited.

Productive Coal Measures have been surveyed in the neighbourhood of Ruabon and Chirk in Denbighshire, and also near Mold and Holywell in Flintshire. Further progress has also been made with the survey of the Upper Barren Measures, which have now been separated into three groups—the Ruabon Marls, the Coed-yr-Allt Group and the Erbistock Beds. The maximum thickness of these measures cannot at present be estimated, but it is certainly very great, and will probably be found to have an important effect in limiting the area over which coals can be worked towards the east under the Triassic rocks.

The northern part of the South Staffordshire Coalfield has been mapped on the six-inch scale, and some additional information, involving a modification of the views expressed on the old map, as to the nature of the disturbances which bound the exposed portion of the coalfield on the east and on the west, has been obtained.

The survey on the northern part of the Warwickshire Coalfield has been continued in the neighbourhood of Kingsbury, and a fairly complete sequence up to and including some of the rocks classed as Permian on the old series map has been established. All the rocks examined up to the present belong to the Coal Measures, but a large tract of the so-called Permian still remains to be surveyed.

In this connection reference may be made to the boring for coal at Ebbsfleet, in Kent, an account of which is given in Appendix I. The boring ended in Carboniferous Limestone at a depth of 1,389 feet.

In Scotland the revision of the Carboniferous areas included in Sheet 31 of the one-inch map has necessitated the survey of a small portion of Fife in the neighbourhood of Culross. Good natural sections in the Upper Limestone and Millstone Grit groups were examined, and some important evidence as to the sequence in that neighbourhood was obtained from bore-sections. An area of Carboniferous Limestone on the south side of the great Lanarkshire Coalfield has been revised, and evidence obtained that these strata were laid down on an extremely uneven floor of Lower Old Red Sandstone rocks.

Work in Coal Measure areas has been carried on in the southern part of the Lanarkshire Coalfield about Wishaw, Larkhall, and Stonehouse. The survey of the eastern part in the Shotts and

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Fauldhouse district was completed, and the field-unit employed in that district was transferred to Ayrshire, where work has been commenced in the Carboniferous Limestone area on the northern side of the coal-basin.

Reference has already been made to the revision of the oil-shale fields. In the palæontological section of the Summary will be found some additional information as to the marine fauna of the Upper Carboniferous rocks of Scotland. The facies of this fauna is similar to that of the fauna described by Messrs. Hind and Stobbs from the coalfields of the Midland Counties of England. It is now generally recognised in Scotland that these marine bands in the Coal Measures, and also in the Carboniferous rocks with which the oil-shales are associated, are persistent over extensive areas and therefore of considerable value in fixing horizons and in interpreting the results obtained in boring for coal or 'shale.'

NEW RED SANDSTONE.

In the Summary of Progress for 1910 reference was made under the heading Permian to certain red beds of doubtful age occurring near Hints, in East Staffordshire, and containing a peculiar limestone-conglomerate. During last year considerable progress has been made in surveying the Triassic rocks situated between the Warwickshire and South Staffordshire Coalfields, and the Hints Beds have been recognised at several places within the area mapped as Bunter by the earlier surveyors. Their relations to the Bunter have not, however, as yet been fully made out. So far as the resurvey of the Midland area is concerned, the Permian question is still unsettled. Certain portions of the series formerly regarded as Permian have been relegated to the Coal Measures, but the upper limit of the Coal Measures has not yet been fixed. In this connection reference may be made to the record of the important boring at Streetly or Little Aston, which, after passing through 77 feet of Bunter Pebble Beds, traversed 1,800 feet of horizontally stratified marls, sandstones and conglomerates.

JURASSIC.

No area of Jurassic rocks has been mapped during the year, but fossils have been collected from a district which had been previously surveyed in the Island of Mull. The examination of these fossils has added to our knowledge of the palæontological succession in that region.

Reference may here be made to a Memoir, published during the year, 'On the Mesozoic Rocks in some of the Coal Explorations in Kent.' It contains much interesting information as to the Jurassic deposits brought to light by the borings and sinkings for coal at Dover, Brabourne, Pluckley, and Penshurst.

CRETACEOUS.

Upper Cretaceous rocks have been surveyed in the London and South-eastern District. It has been found that the Upper Greensand, when traced northwards to the neighbourhood of Wendover, takes on a clayey facies and becomes inseparable from the Gault.

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No signs of erosion have been detected at the base of the Chalk; on the contrary, there appears to be a gradual upward passage from the Gault and Upper Greensand taken together (Selbornian) into that formation. If this view be correct, the line drawn between Upper Greensand and Gault in this neighbourhood is merely of lithological significance.

In the areas composed of Chalk the recognised subdivisions have been delimited on the six-inch maps.

TERTIARY.

In England the work on Tertiary rocks has consisted in tracing the boundaries of the various subdivisions of the Eocene strata in the London and South-eastern District.

In Scotland further progress has been made with the mapping of the igneous rocks of the Island of Mull. The relations of the different varieties to each other, and to the older rocks with which they are associated, are highly complex, and present problems of considerable scientific interest. Portions of the basaltic plateau, composed of successive flows of lava, often marked by reddened upper surfaces, have been surveyed on the south side of Loch Scridain and in the Salen District. At the west end of Glen More a great number of inclined sheets of gabbro or dolerite have been met with, cutting the basic lavas, and also a considerable mass of intrusive granophyre, which is therefore of earlier date than some of the gabbro of this district.

PLEISTOCENE AND RECENT.

The superficial deposits have been mapped in all districts where work is going on. In the low-lying parts of Denbighshire, Flintshire and Cheshire they are extensively developed, and conceal the solid geology over extensive areas in Coal Measures and Triassic districts. Their study has brought to light two interesting cases of diversion of the Dee which are briefly described in the following pages.

In the Warwickshire and Staffordshire districts two types of drift have been recognised—the one a drift from the west, and the other, containing flints, from the east.

In East Sutherland some interesting relics of the later stages of the Glacial Period have been observed, and attention has been paid to the succession of plants in the peat-mosses of that region. A layer containing the remains of sub-Arctic plants is followed in general by the remains of two periods of forest growth, the lower of birch and the upper of pine.

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II.—FIELD WORK.

(A.) ENGLAND AND WALES.

The geological surveying of the three districts which were commenced in 1910 has been continued, namely:—

1. Denbighshire District under Mr. G. W. Lamplugh.
2. Warwickshire District under Mr. G. Barrow.
3. London and S.E. District under Mr. C. Reid.

In addition to the ordinary field-work some important borings made in different parts of the country in search of concealed coalfields have been examined, and the geological maps of Anglesey, recently completed by Mr. E. Greenly, have been checked upon the ground.

1.—Denbighshire District.

G. W. Lamplugh, F.R.S., District Geologist.

C. B. Wedd, B.A.
H. H. Thomas, M.A., B.Sc.
B. Smith, M.A.
L. J. Wills, M.A.
W. C. Simmons, B.Sc.
} Geologists.

The field-work of the year consisted in the survey on the six-inch scale of the southern part of the Denbighshire Coalfield, with tracts of older rocks to the westward, in the Wrexham Sheet (121) of the one-inch map, and the revision of part of the Flintshire Coalfield and the contiguous country around the estuary of the Dee, in the Flint (108) and Liverpool (96) Sheets of the one-inch map.

ORDOVICIAN.

Small tracts of Upper Ordovician rocks were mapped by Mr. Wills in Glyn Ceiriog and by Mr. Wedd on the upland north of the Vale of Llangollen, but it is necessary that a further area be surveyed before any conclusions are drawn.

SILURIAN.

Between the Vale of Llangollen and Glyn Ceiriog the flat-topped hills to the west of the Carboniferous outcrop were mapped by Mr. Wills and found to be mostly composed of gently dipping Silurian rocks of Wenlock and Ludlow age. There is also a small area of Llandovery and Tarannon rocks at Llansantffraid-Glyn-Ceiriog.

The Wenlock-Ludlow rocks appear to be disposed in a shallow broad syncline whose axis runs a little south of east. The dips rarely exceed 10°-15°, and in many parts 6° is more common.

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The *lithology* is decidedly monotonous. For the most part the rocks are fine-grained indurated shale, more or less cleaved. Interstratified with these there are also calcareous and silicious flaggy beds, much less or not at all cleaved though apparently little different in texture from the shale. At the same time, at least at one horizon and possibly at others in the sequence, although the tops and bottoms of the flag-beds are practically parallel and undisturbed, yet the material between is crumpled and strongly overfolded; which suggests that, under compression, while the shales were cleaved and moved along the top and bottom of the flag-bed, the silty particles of the latter were rearranged in folds.

The fossils, mostly graptolites, collected from this monotonous series of beds have been identified by Miss Elles. The mapping brings out the following sequence in descending order:—

4. A great thickness of shales and flags incapable of subdivision.
3. A series of internally crumpled silty flags of the type above described which are interbedded with shales. The flags are often highly calcareous but not universally so. In the series are a few thin limestone bands crowded with fossils, and at one place, near Llwydiarth, Dôl-y-wern, a coarse conglomerate has been noticed. The fossils indicate the zone of *Monograptus nilssoni* (Lower Ludlow).
2. A thin-bedded micaceous flaggy and slightly sandy shale-series, with thin bands of internally crumpled flags towards the top, unfossiliferous.
1. A thin-bedded banded, earthy-weathering micaceous shale-series with some flags, which has been somewhat extensively quarried in the Glyn valley. This is as yet the only division which it has been found possible to map separately. The fossils indicate the zone of *Cyrtograptus murchisoni* (Base of the Wenlock).

CARBONIFEROUS LIMESTONE

In the neighbourhood of Minera the sequence of the Carboniferous Limestone has been examined by Mr. Wedd. Here the lowest members are overlapped, but they are met with farther south. Mr. Wedd finds the complete sequence in its fullest development, in the escarpment of the Eglwseg Rocks between Llangollen and Minera, to be as follows in descending order[1]:—

g. More or less sandy grey and brownish grey limestones, sometimes slightly pebbly. *Productus giganteus* Mart. and crinoids usually abundant. Thickness, approximately 25 feet.	
f. A variable group of rather fine-grained and more or less pebbly calcareous grits, alternating with gritty limestones which often contain rather large quartz pebbles: the lower part of this group seems in this district always to consist of current-bedded hard flaggy grey sandy limestone with an oolitic structure developed around the minute sand grains: fossils not abundant, but *Productus*, crinoids and some Dibunophyllid corals occur. Thickness approximately 100 feet.	'Sandy Limestone' (Morton).

[1] The sequence has previously been examined and measured in detail by G. H. Morton and earlier geologists. Many of the following estimates of thickness are taken from Morton's account ('The Carboniferous Limestone and Millstone Grit of North Wales,' *Proc. Liverpool Geol. Soc.*, vol. iii, 1876, p. 152).

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e. Grey somewhat muddy limestones of dark and lighter shades, thin-bedded, with thin grey shaly partings. Brachiopods and corals very abundant, especially in the upper part, which contains extensive coral-beds: *Lithostrotion* of the types of *irregulare*, *martini* and *junceum*, also a basaltiform species given in old lists as *L. portlocki* Bronn, are all abundant, as are also *Lonsdalia duplicata* Mart., and several forms of *Dibunophyllum*, while *Lonsdalia floriformis* Flem., *Aulophyllum*, Campophyllid corals, *Cyathophyllum regium* Phill. or a variant, and *Syringopora* are also found. Of brachiopods, *Productus giganteus* and other productids, *Spirifer* and a small *Chonetes* are abundant: crinoids are numerous; and a Fenestellid bryozoan occurs. Thickness about 250 ft.	'Upper Grey Limestone.'
d. A thick group of massive "white" limestones, partly creamy-white and partly of a yellow or pale fawn colour, sometimes passing up gradually into the overlying grey limestone. Some beds of a very fine grain, with a porcellanous texture, resemble the 'Holystone' of the 'D1' limestone in north-east Derbyshire: other beds have a rubbly structure. Near the Dee valley, several bands of purple shale, sometimes 10 feet or more in thickness, separate these limestones. The shale underlying the most conspicuous escarpment ('thick-bed' of Morton) of the Eglwseg Rocks has, at the top and near its base, bands of rolled gravel composed almost entirely of purple shale pellets with occasional pebbles of vein-quartz and other extraneous rocks. These purple shale-beds disappear northwards between the Dee valley and Minera. The highest part of the group contains *Lonsdalia floriformis*, and *Dibunophyllum* occurs lower; few corals were found in the lower part, but there is a bed of drifted *Alveolites* (?) and *Syringopora* not far from the base near Minera. Small Bellerophons and larger turreted gasteropods are abundant in certain beds near the top and bottom of the group. At the Minera quarries these beds rest directly on the Ordovician, and contain near their base bands of pebbles and layers of green shale evidently derived from the denudation of the rocks of that system. One of the pebbly beds is full of a giganteid *Productus*. Maximum thickness of the group, about 420 feet diminishing southwards and northwards to 220 feet or less, according to Morton.	'Upper' and 'Lower White Limestone.'
c. Dark and lighter brownish-grey earthy limestones, massive, with thin shaly partings. A giganteid *Productus* abundant.	'Brown Limestones.' 360–480 ft.
b. Thin-bedded grey earthy limestones and grey calcareous shales.	
a. Red basement-beds: not yet examined: but they contain purple shale with rolled shale-gravel like that in (*d*).	

The basement-beds, which are present below the Eglwseg Rocks north of Llangollen, soon thin away northwards and southwards, as do also the groups *b* and *c*, the latter of which, persistent at least a mile northward of Craig-y-Forwyn, dies out completely before reaching the Minera quarries. South of the Dee valley the overlap of the lower beds has proceeded further, for at Fron-Cysyllte, only about 30 ft. of the "white" limestones *d* remains below the upper grey group *c*, which, together with the sandy limestones and calcareous grits, makes up almost the whole formation (*see also* Morton, *op. cit.*).

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It thus becomes evident that the pre-Carboniferous floor was uneven in the neighbourhood of Minera, its slope, as it rises westward from beneath the limestone, appearing to exceed the dip of the limestone.

No evidence of the development of *Cyathaxonia* beds (D3) has been detected in the highest part of the limestone.[1] It is not unlikely that the prevalence of sand instead of mud prevented the development of the characteristic fauna. The upper *Dibunophyllum* or *Lonsdalia floriformis* (D2) fauna is well represented throughout the upper grey limestone and in the upper part of the "white" limestones *d*, but its downward limit has not yet been determined.

The continuation of the Carboniferous Limestone outcrop south of the River Dee was surveyed by Mr. Wills, who recognised the same general succession as the upper part of that described by Mr. Wedd. The divisions *a*, *b*, and *c* of this classification appear to be absent, and, as above noted, only about 30 feet of group *d* is seen at Fron-Cysyllte. There is here a thin bed of red shale near the base, comparable to those occurring in group *d* in the Eglwseg escarpment.

In this district the main mass of limestone, 100-120 feet thick, belongs to the 'Upper Grey Limestone Series' of Morton (*e* of Mr. Wedd's classification). In the Ceiriog and Morlas valleys this is still the case, but there is no good evidence about the age of the lowest beds here. Though the thickness is not easy to estimate, it is improbable that the beds up to the top of group *e* exceed 350 feet.

The "sandy limestone" series (groups *f* and *g*) is more strongly developed south of the River Dee, and while resembling the beds described by Mr. Wedd, is remarkable as being probably 350 feet thick in the Ceiriog Valley. A thin limestone is here taken as the top. The series contains limestones, pebbly and sandy limestones, fine-grained calcareous grit with seams of pebbles and scattered pebbles. Some of the calcareous grits have the oolitic structure described by Mr. Wedd. *Productus giganteus* occurs in one of the limestones.

MILLSTONE GRIT.

On the north side of the Vale of Llangollen and the high moorlands of Ruabon Mountain the Millstone Grit Series was mapped by Mr. Wedd, who reports that it consists essentially of sandstones and grits with subordinate shales, and has in this district a thickness of about 650 feet. The greater part of this sequence is composed of numerous bands of fine-grained whitish grit or sandstone, often quartzitic, with frequent pebbly seams which exhibit a great uniformity of type and recall by their

[1] Messrs. Hind and Stobbs have recorded *Cyathaxonia* from the "Aberdo" limestones of Flintshire. "The Carboniferous Succession below the Coal-Measures in North Shropshire, Denbighshire and Flintshire," *Geol. Mag.*, dec. v vol. iii, 1906, p. 458.

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lithological character the " Yoredale Sandstones " of North Staffordshire.[1] In the highest part, however, there is a considerable development of coarse-grained current-bedded felspathic and more or less pebbly grit (Aqueduct Grit or Garth Stone) of a different type, like the coarse-grained Millstone Grits of the English Midlands. The felspars of this Grit are kaolinized. Below the middle of the series the " chert-beds " can be recognised north-west of Trevor and on the slope of Ruabon Mountain, where they consist of a more or less cherty gannister-like sandstone, quarried for road-metal, above a cherty shale which is also exposed in the grounds of Argoed Hall west of the Dee Bridge.

Morton has given a detailed account of the sequence (*op. cit.*, p. 190), assigning the coarse-grained Aqueduct Grit and the fine-grained sandstone (' Dee Bridge Sandstone ') next below it to the Millstone Grit; and all the rest, including the sandy limestone to the ' Yoredale Shales.'

Several of the fine-grained lower grits contain *Spirifer* and other brachiopods. On Ruabon Mountain a very fine-grained gannister-like rock some distance below the ' cherty beds ' yields a small *Productus* and several other brachiopods in abundance, while above the ' cherty beds,' further down the slope, a one-inch band of brown limestone and a few inches of calcareous shale above it are crowded with brachiopods. This fossil-bed occurs in the midst of shales that evidently belong to Morton's ' Lower Shale with Fireclay and bands of Limestone.' North-west of Trevor a thin bed of coal has been reached by adits in a somewhat higher shale.

Compared with the marine molluscan fauna of the Midland Millstone Grits, that of the Denbighshire series shows a marked contrast of character and distribution. For in the Midlands marine shells are rarely found in the grit-beds, while *Goniatites*, *Pterinopecten* and *Lingula* are found frequently in the associated shales. Here, on the other hand, a fauna, chiefly of brachiopods, occurs more frequently in the grits than in the shales.

In the country south of the Dee surveyed by Mr. Wills, the base of the Millstone Grit was difficult to trace, owing to the rarity of exposures in the top limestone of the underlying sandy limestone series, since the lithology of the two divisions is otherwise rather similar. The grits in the Millstone Grit Series are, however, usually less calcareous and have yielded fossils in two localities only. The upper part of the series is composed of the ' cherty beds,' which consist of true cherts, cherty shales, gannister-sandstone, and silicified limestones and rotten-stone with many fossils.

Some conglomeratic beds furnishing indications of contemporaneous erosion were observed in the series, but the exposures of the conglomerate do not appear to be all on one horizon. The best exposure is almost half a mile E. by S. of Craignant where a cross-bedded conglomerate, containing large blocks of cherty shale, pebbles of a compact quartzite and of quartz, is seen resting on an eroded surface of cherty shale with chert-nodules.

[1] This resemblance was pointed out by A. H. Green, *Geol. Mag.*, vol. iv, 1867, p. 11.

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The upper boundary of the series is taken at the top of the highest cherty shale and is seen in the Ceiriog Valley only, where it underlies a gannister-sandstone.

LOWER AND MIDDLE COAL MEASURES.

The outcrop of the Lower and Middle Coal Measures in the neighbourhood of Ruabon was mapped by Mr. Wedd, who reports that exposures of the lowest measures near Trevor show that the 'Holywell Shale' facies does not persist as far south as there. The productive measures attain a thickness of probably between 1,800 and 1,900 feet, including about 14 workable coal-seams and several valuable fireclays. The more important coals are grouped in the middle portion of this thickness, with the Main Coal, the principal seam of the district, in the lower part of their sequence. The fireclays and gannisters that are worked for the manufacture of drain-pipes, &c., and fire-bricks lie entirely below the Main Coal, and are associated with the Chwarele, Llwyn-einion, Wall and Bench, Upper Half-yard and Stone Coals, in ascending order.

The Measures consist essentially of shales with few beds of sandstone, and these of no great thickness, except in the upper part, where the massive Cefn Sandstone, the chief building stone of the neighbourhood, makes a prominent landmark, and is repeated by strike-faults westward of Ruabon. On comparison of sections in neighbouring parts of this district, considerable variation of detail is observed; but in spite of this, such seams as the Llwyn-einion, the Wall and Bench, Nant, Yard, Main, New or Quaker and Cefn Coals (in ascending order) can be traced throughout.

Except that some of the smaller coals are still raised in the mines that work the principal fireclays in the proximity of their outcrop, the more valuable coal-seams have long since been worked out at shallow depths, and serious coal-mining is now practically confined to the winning of the Wall and Bench, Main and Quaker Coals, which are followed to considerable depth and distance eastward down the dip.

The rarity of fresh-water or estuarine mollusca contrasts strangely with their abundance in the corresponding strata of the Midland Coalfields.

South of Chirk, in the country surveyed by Mr. Wills, the Coal Measures are almost wholly concealed by drift and were only seen at the surface in some limited exposures in the banks of the Ceiriog.

In Flintshire, small areas of Coal Measures were mapped by Mr. Thomas in the neighbourhood of Mold and by Mr. Smith in the neighbourhood of Holywell, but in both districts the exposures were scanty, owing to the deep covering of drift. The 'Holywell Shales' were best seen in the deep valleys east and south-east of Holywell; and the overlying alternations of siliceous grit, sandstone, shale and sandy shale, grouped collectively, under the term 'Gwespyr Sandstone,' were examined in the ravine near Stockyn Hall and Plas Llanerch-y-mor. The Coalfield is much faulted and the details of its structure can only be ascertained from underground workings.

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RUABON MARLS.

The red or purple marls overlying the Middle Coal Measures are well developed in the Ruabon district. Where mapped by Mr. Wedd they must attain a thickness of somewhere about 900 feet, to judge by the depth of the Main Coal beneath the Coed-yr-Allt escarpment in Wynnstay Park. The outcrop of these soft marls occupies a broad drift-filled valley between the escarpments of the Cefn and Coed-yr-Allt sandstones, and several strike-faults obscure the sequence as exposed in the valleys of the Dee and its tributaries and in the large clay-pits, so that no complete section is seen.

Southward from Ruabon Mr. Wedd notes that a hard micaceous sandstone 10-20 feet thick is often seen at the top of a small sequence of shales with thin coal-seams above the Cefn Rock, and marks a convenient base-line for the Ruabon Marls, which are seen to come on immediately above it. Near the base, and at intervals higher up in these marls, occasional beds of pale greenish-grey marls are found, but the greater part of the sequence consists of deep-purple marl more or less streaked and mottled with pale greenish-grey. In the proximity of the Dee Valley beds of coarse yellowish grit, often with large pebbles, are seen in the lower part of the marls, but have not been observed further north, where their apparent absence may possibly be due to faulting. It seems to be only the lower half of the series that is worked for brick- and terra-cotta clay, all the clay-pits showing a considerable thickness of purple mottled marl, while the Hafod-y-Bwch clay-pit alone, lying a little further eastward than the others in relation to the strike, shows, in its upper yart, redder clays with a band of dark carbonaceous shale and several thin beds of grey or yellow limestone, some of which contain *Spirorbis* and Entomostraca. In stream-sections these *Spirorbis*- and entomostracan-limestones, seldom more than a few inches thick, are frequently seen, but only in the upper part of the sequence. In Wynnstay Park, and also near Chirk, a double band of limestone, one or both bands containing *Spirorbis* and Entomostraca, occurs immediately below the Coed-yr-Allt beds, just as a similar double band of limestone is found below the Newcastle Beds in North Staffordshire.

COED-YR-ALLT GROUP.

Immediately above these limestone bands, pale-grey shales with numerous Entomostraca pass upwards into pale shaly sandstones with alternations of similar and darker shales, several *Spirorbis*-limestones, and at least two small coal-seams. Somewhat higher, a thicker coal with underlying fireclay is succeeded by more massive whitish sandstones, which in the valley of Afon-Eitha near its junction with the Dee are separated from one another by beds of purple shale.

Elsewhere it may be that these sandstones coalesce to form the prominent escarpment which usually marks the outcrop of the Coed-yr-Allt beds; and in the northern part of Wynnstay Park a thicker bed of this sandstone, there quite a free-stone, has been quarried for building purposes. The whole group may attain a thickness of 300 feet.

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ERBISTOCK BEDS.

This name may appropriately be applied to the thick series of red and purple sandstones with conglomeratic bands and much red marl, which overlies the Coed-yr-Allt group, since the strata in question are best exposed in the gorge of the Dee around Erbistock as described in the last Summary.[1]

In the tributary of the Afon-Eitha that flows across the strike of these beds from Belan Place, the Coed-yr-Allt sandstones are surmounted by a speckled purplish-brown felspathic sandstone, noted last year by Mr. MacAlister. This sandstone closely resembles a common type of the Keele Beds of North Staffordshire, and may be taken as the base of the Erbistock Beds. It is probably separated by faults from the main exposures further east.

FAULTS, ETC. OF THE RUABON-CHIRK DISTRICT.

The Carboniferous strata in the neighbourhood of the River Dee examined by Mr. Wills and Mr. Wedd are characterised by an uniformity in direction and amount of dip. The former is about E. 20° S. while the latter varies as a rule between 10° and 20°.

This uniformity is maintained despite the presence of numerous strike-faults which in the Chirk district to a great extent counterbalance the dip. Near the River Dee the faults range about N. 30° to 40° E., but as traced south some of them seem to swing round to a nearly E.-W. direction. In this part of their course they are dip-faults.

Faults belonging to this N. 40° E. series separate the Carboniferous from the Silurian outcrops from near Fron-Cysyllte to the southern side of the River Ceiriog near Henmer House. The main fault probably cuts out the limestone and part of the sandy limestone-series for about 1½ miles through Chirk Castle Park, but the junction is generally hidden by drift.

Another large fault of this series passes just west of Chirk Castle and throws down the Millstone Grit on the west against the sandy limestone series below the Castle. Near Newhall the strong springs coming out through the drift, which supply Chirk with water, are probably thrown out by this fault.

A master-fault with a downthrow west of 300-400 feet ranges through the workings of Black Park and Brynkinalt collieries from NE. to SW., but appears to be traceable into the E.-W. fault which throws the limestone-outcrop to the west near Henmer House.

Other faults of the same series, some with large throws, have been met with in the colliery-workings, but their surface outcrops are generally concealed by drift. As was suspected last year, there is no large fault along the face of the Coed-yr-Allt escarpment.

[1] The term 'Wrexham Red Sandstones and Marls' suggested for these beds by Dr. Gibson (*Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 261) is less appropriate, as the strata under the town of Wrexham are deeply buried by drift and may not belong to this division.

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The surface-position of the main Viaduct fault (*see* Summary for 1910) has been traced by Messrs. Wedd and Wills. The latter finds that it runs from about a mile E. of Pen-y-lan Bridge to the bridge in almost an E.-W. direction. From thence it swings south-west and then north-west again, passing between Coed-leoedd-uchaf and -isaf. It regains an E.-W. trend in Halton Woods, which it maintains to near Fron-Cysyllte.

In its western continuation traced by Mr. Wedd the main fault crosses the river in a west-north-westerly direction at the bend north of Argoed Hall, where its position can be closely located: and, after throwing out several strong springs below the road to Llangollen, assumes a more westerly trend for a short distance, but soon returns to a west-north-westerly course along the foot of the Eglwseg Rocks. The dislocation is seen in the stream-valley above Ty-Canol.

A southerly offshoot of the main fault, in the ground surveyed by Mr. Wills, has been encountered in some old workings near Pentre and Black Park. It too can be traced running almost due E.-W. to Fron-Cysyllte. Here other faults connected with the same disturbance but of less importance were mapped.

It is not easy to estimate the throw of the main Viaduct fault, because of the strike-faulting which appears to repeat the outcrop of the Coed-yr-Allt series four times, and that of the Cefn Rock three times, on its northern side. Similar though less well-displayed repetitions occur on the south side also. But at the bend of the Dee near Pentre an approximate throw of 1,200 feet has been calculated.

North of the Dee fault, Mr. Wedd found that most of the dislocations that intersect the Coal Measures still follow the direction of strike, with which many of them swerve from a north-north-easterly to a northerly trend beyond Ruabon. As proved in the earlier workings of the Wynnstay and neighbouring collieries, these faults tend to run in small groups throwing alternately east and west, so as to produce submerged troughs and ridges in the measures, without, however, seriously affecting the position of seams as determined by the dip on either side of the disturbed area. Further east, as far as the colliery-workings yet extend, the faults met with have a general easterly downthrow, which may be expected to give place to upthrows when the seams have been followed further.

Transverse faults are rarely found. Of these the most important is the Ty-Gwyn fault, with southerly downthrow, north of Rhos.

TRIAS.

The area in Cheshire, surveyed by Mr. Lamplugh and Mr. Simmons, between the mouth of the River Dee and Little Sutton, is underlain by Triassic rocks which are, however, for the greater part concealed by a thick cover of drift. The steep bank, from 20 to 50 feet high, formerly a cliff bordering the estuarine flat and running north-westward from Blacon Point, is composed altogether of drift until it reaches Burton Park, where Bunter sandstones emerge and form the bluff of Burton Point. At the southern end of this bluff a massive coarse sandrock containing

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many pebbles rests with a sharp junction on softer fine-grained green-mottled sandrock without pebbles, of which over 20 feet is exposed. The section was figured many years ago by Prof. E. Hull in his memoir on the Triassic and Permian rocks[1]; it is the best evidence to be found in the district for the separation of the Bunter Pebble Beds from the Lower Mottled Sandstone. In some sections farther north, however, the two types appear to be intercalated, this being particularly marked in the railway-cuttings, examined by Mr. Simmons, between Hadlow Road and Neston and between Little Sutton and Hooton, where thick bands of soft loamy sandrock, with marl-partings and without pebbles, occur among the coarser sandrock of 'Pebble Beds' type. In the village of Burton some exposures of the Lower Mottled Sandstone bring out its cross-bedded structures with remarkable distinctness. In the undulating ground to the northward, stretching from Burton through Ness to Neston, the Pebble Beds are generally close to the surface and are well seen in many old quarries, road-cuttings, &c. The rock is still quarried in Hadden Wood. Coarse sandrock also emerges from beneath the drift near Little Sutton; at Ledsham, in the valley near Woodbank Hall; and a few other places.

SUPERFICIAL DEPOSITS.

Glacial.

The low plateau on the Cheshire side of the estuary of the Dee, surveyed by Mr. Lamplugh and Mr. Simmons, is mainly composed of stiff red boulder-clay, with intercalated sheets of soft yellow sand. This drift rests on an uneven surface of the Triassic rocks, which is deeply buried in the southern part of the area around Saughall, Mollington and Capenhurst, but emerges in places on the rising ground to the north and north-west. The thickness of the drift is therefore very variable, probably reaching its maximum in the partly obliterated old valley beneath the recent estuarine flat of the Dee, where borings have proved the superficial deposits to extend in some places to a depth of over 200 feet below sea-level.

The tracts of boulder-clay north of the estuary are characterised by a remarkably even surface, broken only where the ground is channelled by streams or where lenticles of sand make slight rises in emerging at the top.

The boulder-clay contains many more stones and boulders than that of the country east and south-east of Wrexham, described in the last Summary, and the fragments of marine shells, that occur in both districts where the clay is unweathered, are here notably more abundant and larger. The clayey matrix is decidedly calcareous where fresh, but is usually decalcified to a depth of two or three feet from the surface. Formerly the boulder-clay was dug on an extensive scale in the district for marling the land; and old marl-pits, now serviceable as ponds, are numerous wherever the boulder-clay is present. The matrix of the boulder-clay

[1] 'The Triassic and Permian rocks of the Midland Counties' (*Mem. Geol. Surv.*), 1869, p. 40.

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appears to have been derived mainly from Triassic and Carboniferous strata, but a large proportion of the boulders are of granitic and volcanic rocks from South-west Scotland and the Lake District. Mr. Simmons found that a rough classification of 100 boulders thrown aside at the Whitby Heath brick-pit gave the following result:—

Palaeozoic volcanic rocks	47
Sandstones, grits and quartzites ...	34
Granites and granitic rocks ...	14
Carboniferous limestones	5
	100

The Glacial sand of the district does not form a continuous bed, but occurs in detached patches. It is generally fine-textured, with loamy bands and streaks of clay, sometimes passing into laminated silt and leaf-clay. It occasionally includes seams of small gravel, but as a whole is remarkably free from coarse material. The outcropping patches generally pass in lenticular form beneath the surrounding boulder-clay, and their continuation is revealed in several places between separate bands of boulder-clay in sections afforded by ravines and railway-cuttings.

On the opposite or Flintshire side of the estuary, in the tract around Holywell surveyed by Mr. Smith, the glacial deposits comprise a lower boulder-clay which, at its base, is chiefly made up of débris of the local rocks, but in its higher part consists largely of Triassic debris probably derived from the bed of the Irish Sea.

Above the lower boulder-clay, sands and gravels, sometimes well-stratified, occur in places, especially in embayments of the rising land-slope; as for example in the Holywell-Greenfield valley, where sections over 60 feet in height are exposed in the cutting of the old mineral-line on the east side.

The sands and gravels are sometimes covered by a red upper boulder-clay, hardly differing from the higher part of the lower clay, and small patches of sand are locally developed at different horizons in the two clays.

In all these deposits there are erratics from distant sources, as well as from local formations. Boulders of northern granites, and of volcanic rocks from the Lake District, are of common occurrence.

In several places, marine shells in a fragmentary state were found in the coarser sands and in the boulder-clay. They are quite common in the boulder-clay of the Mostyn Brickyard, west of Llanerch-y-mor.

The broad and deep valley of Nant-Flint, which runs in a south-easterly direction nearly parallel with the shore of the Dee estuary for four miles, from the outskirts of Holywell, appears to be, at least at its western end, a trench cut by the marginal drainage of the ice-sheet, during a stage when it filled the estuary and covered the rising ground for about $1\frac{1}{2}$ miles inland. The direction of this valley is quite different from that of the normal drainage, which runs directly to the coast line.

The trench-like aspect of the valley is somewhat disguised by extensive landslips of the Carboniferous shales and boulder-clay

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on the south-western side. Near Milwr the floor forms a watershed from which small streams flow in opposite directions. The northern stream, occupying the valley east of Pen-y-maes, reaches the estuary about ½ mile south-east of Greenfield; and the southern, after flowing down the old channel, turns abruptly to the north to the coast near Flint.

The stream east of Pen-y-maes is re-excavating an old drift-filled channel at its mouth, but the head of its valley, where it taps the marginal trench, seems to be entirely Post-glacial.

In the tract near Mold, mapped by Mr. Thomas, the drift is of three types, (1) stiff boulder-clay, partly covered by (2) moundy sands and gravels; and (3) a younger terrace-like series of gravel and sand, which appears to be connected with the existing valley-system. The moundy gravels (2) are well represented S.W. of Mold around Tower and Waen Farm, and the terrace-like gravels are developed in the valley of the Alyn around the town of Mold.

In the Ruabon district, mapped by Mr. Wedd, drift almost entirely covers the Coal-Measures ground and creeps for some distance up the dip-slope of the Millstone Grits of Ruabon Mountain. But the bold escarpments of the Coed-yr-Allt and Cefn sandstones partly rise above it; and in a few places it has been so far removed as to expose small areas of lower-lying Coal-Measure shale. This drift consists at the surface mainly of boulder-clay, sometimes red, sometimes grey or yellow, according to the nature and state of weathering of its material. Sometimes, as in the Hafod-y-Bwch clay-pit these materials are seen to have remained unmixed, and exhibit a sharp line of junction one with another. No persistent sequence has been recognised. The matrix and included stones, often striated, show a mixture of local material with North-country boulders. White granites are of frequent occurrence on the lower slopes of Ruabon Mountain, as observed further north last year by Mr. Thomas.

Associated with these boulder-clays are sheets and moundy patches of quartzose sand and gravel. As regards their distribution at the surface the gravels fall into two groups; (1) flat spreads of gravel, rarely moundy, cover considerable areas of the surface in the drift-filled hollow between the sandstone ridges of the Cefn and Coed-yr-Allt Rocks and seem to have been deposited by flood-waters gradually accumulating into definite channels during the later stages of glaciation; (2) a chain of hillocks, mainly composed of sand and gravel, fringes the lower slope of Ruabon Mountain and conforms roughly to the contour of the ground. This gravel seems to have been formed as a wash from the bare grit slopes on to the edge of the receding ice-sheet. From Ruabon Mountain it descends for some distance along the margins of stream-valleys, and at Pen-y-Cae forms a low esker-like ridge.

On the slopes of the Dee Valley eastward of Llangollen a roughly-stratified gravelly deposit of considerable extent and thickness forms a terrace-like ledge above the highest river-gravel. It consists mainly of large and small rolled fragments of Silurian shale, and appears to have been derived by washing from the unstratified drift on the higher slopes.

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West of Minera a thick sheet of boulder-clay, composed of material brought by the Welsh ice, without any admixture of northern granites, covers the lower slopes of Cyrn-y-Brain and fills a broad depression in the Carboniferous Limestone. Further south, patches of it have been carried across the Millstone Grit escarpment and extend within a short distance of the eastern drift-sheet which contains northern erratics. Numerous large boulders of basic or intermediate igneous rocks, doubtless of Welsh origin, are scattered over the higher limestone ground in this neighbourhood.

Shell-fragments are of frequent occurrence in the gravels and boulder-clay of the low ground on the east of the district, and were found also in the high-level gravels along the foot of Ruabon Mountain.[1]

In the tract south of the Dee, mapped by Mr. Wills, the low-level glacial deposits continue to form an undulating plateau up to, and beyond, the southern edge of Sheet 121. In the neighbourhood of Ellesmere the drift is chiefly boulder-clay with lenses of sand, and its surface is diversified by numbers of kettle-holes as many as 29 occurring in three square miles. Many of these have held lakelets but all in the area surveyed are now silted up with clayey silt, peaty silt, and peat.

The rough three-fold division into an upper and a lower boulder-clay, separated by sand, noted last year in the ground near the Dee, was found to persist to some extent near the Ceiriog, being seen in the Morlas Valley also up to Esgob Mill; but as the hills are approached the arrangement is complicated by the appearance of Welsh drift which mainly overlies the Red drift from the North. The mingling of the two drifts is remarkably slight.

The Ceiriog has nearly cut through the drift which fills the floor of its preglacial channel and displays red boulder-clay underlying Welsh stony drift. Near Pont-faen and below Chirk a red and green laminated silt is associated with the red boulder-clay. The same boulder-clay can be traced up the valley as far as Castle Mills, and extends up the Brookside valley, with fragments of shells, up to 1,000 feet above O.D., and to nearly the same height on the dip-slope of the Millstone Grit between the River Ceiriog and the Morlas Brook. In all these places it is overlain by very stony grey Welsh drift composed almost entirely of Silurian and Ordovician fragments. A similar Welsh drift covers the slopes of the hills in Chirk Castle Park and occupies the bottoms of the valleys in the Silurian country.

Gravels of the Welsh type are also spread out as flats near Chirk and in the Rhyn Park, and are presumably early flood-gravels of the postglacial Ceiriog. They are, however, continuous with esker-like gravels near the Quinta and Chirk Bank, though these do not seem to be so entirely Welsh in origin.

The Welsh drift in the higher parts of the Ceiriog valley and neighbouring uplands is remarkably stony and at some places in the valley resembles morainic material. As this drift everywhere

[1] Mackintosh had previously recorded their presence in gravel pits near Mountain Lodge, at more than 1,000 feet O.D., *Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, p. 360.

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contains 80-90 per cent. of stones it is difficult, in the absence of good exposures, to distinguish boulder-clay from gravel.

Two remarkable cases of diversion of the Dee by glacial damming are exhibited in this area. The first is the Pengwern valley near Llangollen, a large through valley of the dimensions of the Dee valley west of Llangollen but without through drainage. Its floor is composed of glacial drift, well seen in the Cyflymen stream; a kettle-hole on the surface of this drift, at one time a peat-bog, is now drained, and the waters of the stream which reaches the valley at Ty'n-y-pistyll are sent in part to the Cyflymen and so to Llangollen, and in part to the Dee near the Golf Links.

The present Dee runs through a gorge of later excavation between Llangollen and the Golf Links. Gravel from this gorge spreads out as a fan on the drift of the Pengwern valley.

The second diversion is far more important, as it involves the desertion by the river of its old course for many miles and the cutting of a new gorge, 10 miles long, from the Railway Viaduct at Cefn to below Overton Bridge. Just above this new gorge, drift has been observed near the viaduct at river-level, while, in the gorge, the base of the drift is at least 50 feet and in many cases 150 feet above the river level until Erbistock is reached. The old course, therefore, cannot have been by way of the present valley, but seems to have occupied drift-filled hollows which can be traced southward from the Viaduct to Chirk, the ridge on which Black Park and Chirk Green are situated being its eastern edge. Two boreholes show great thicknesses of drift in this valley, one just west of Black Park Lodge having ended at 130 or 140 feet when still in drift, and another at the Wharf passing into solid rock at 142 feet down. The former shows the rock-floor to be less than 170 feet and the latter 200 feet above sea-level. The top of the rock-surface near the Viaduct is at about 175-180 feet above O.D.

It has already been mentioned that the Ceiriog above Chirk occupies an old drift-filled valley. This valley joins the buried channel above described at Chirk, and the stream flows on boulder-clay both above Chirk Bridge and below it almost as far as Lady's Bridge. Here at 200 feet above O.D. it enters the solid rock-gorge through which it now flows to the Dee. It appears most likely, therefore, that in pre-glacial times the Ceiriog had its junction with the Dee at Chirk. The pre-glacial course of the latter river cannot be traced further with any precision, but that its course was to the south or south-east rather than to the east is likely in view of the unbroken ridge extending along the eastern side of the Morlas Brook to Esgob Mill, which probably represents the drift-buried escarpment of the Coed-yr-Allt Sandstones. The line of the St. Martin's Moor valley seems a more probable direction beyond Esgob. The last outcrop of solid rock in this direction lies between St. Martin's Church and Pen-y-Bryn and would presumably form part of the north-eastern valley side.

Late-glacial and Post-glacial.

The high terrace-like expanse of gravel which was mapped in 1910 near Brynkinalt is proved to be continuous with a big spread

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of gravel at Chirk, which is evidently an early gravel of the post-glacial Ceiriog. A similar gravel is found in the Rhyn Park.

For some time after the close of the Glacial period the Morlas Brook seems to have been a tributary of the Severn, but it now joins the Dee. Near Esgob Mill it is evident that originally the brook flowed past St. Martin's Moor in the broad almost dry valley through which the canal runs. But it has been intercepted by a tributary of the Ceiriog, which has cut back a gorge; and now there is a sharp contrast between the open valley above Esgob Mill and the deep gorge through which it runs to the Ceiriog.

Higher up the valley the watershed is so ill-defined that springs arising at Pentre-Kenrick from one side of a delta-fan flow to the Severn, and on occasions water is diverted from the Morlas by a small weir into this drainage.

ALLUVIUM.

The flats of the Dee estuary east of Shotton, over two miles in breadth, being protected by embankments, are cultivated. The subsoil as far as Blacon Point is usually a soft loamy sand containing estuarine shells, mostly *Tellina balthica* and *Cardium edule*, but the soil becomes rather stiffer, from the admixture of silty or clayey wash, in the neighbourhood of the present river and in a strip along the northern edge of the flat which receives the down-wash from the plateau of boulder-clay. Many of the small gullies notching the edge of the plateau have thrown out well-marked fans of detritus on to the margin of the flat, and these fans must have been spread since the time when the course of the river lay close under these northern bluffs, *i.e.*, within the historic period. A few broader hollows, now carrying no appreciable drainage, are without delta-fans; and these evidently mark the course of the older streams, now artificially diverted, which in their day emptied directly into the main river. A rough calculation might be made here of the quantity of material brought down to the flat in a known period of time.

2.—Warwickshire District

Mr. G. Barrow, District Geologist.
Dr. W. Gibson.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. C. H. Cunnington, B.Sc.
} Geologists.

During 1911 the mapping of the area about Walsall, Lichfield and Tamworth contained in the one-inch map 154 was nearly completed, but there remains a considerable amount of information from old mine plans and borings to be dealt with before any opinion can be formed of the exact limits of the concealed Coal Measures between the South Staffordshire and Warwickshire Coalfields.

THE CAMBRIAN ROCKS.

Cambrian Rocks have been mapped by Mr. Barrow about Dosthill, two and a half miles south of Tamworth, where they form

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an inlier about one and a half miles long by about half a mile broad. The dominant rock is a buff-coloured shale, apparently destitute of fossils; but there are also present some thin dark bands from which Mr. Pringle has obtained sufficient fossils to confirm Mr. Jerome Harrison's identification of the shales as Upper Cambrian.[1]

These Cambrian Rocks rise abruptly from the Tame valley and overtop the surrounding area not so much owing to the inherent hardness of the shales as to their having been here penetrated and hardened by numerous igneous intrusions.

Their relations to the surrounding strata are in part obscure. At the northern end of Dosthill they are unconformably covered by Keuper sandstone, small patches of which still cling to a steep face of the old rocks. Keuper Marl is faulted against the sandstone, and further south against the Cambrian, along a line of dislocation which appears to have been initiated in pre-Triassic times.

The junction of the Cambrian and Coal Measures on the east side of Dosthill has been complicated by considerable post-Carboniferous movements. The dip of the coals rapidly increases to verticality as the Cambrian is approached and there must be a break of some kind, yet in a small lane leading from the high road to the village of Dosthill the lowest coal-seam has been cut open, standing on end, while all the others appear to come on in their natural order. The most likely explanation is that there is here some small and local overthrusting though for the most part the Coal Measures rest naturally on an eroded surface of the Cambrian shales.

SILURIAN ROCKS.

The Silurian rocks, which occupy several square miles near Walsall, have been examined by Mr. Cantrill. He finds that they have a north-westerly dip at a low angle and in this direction pass under the Coal Measures which rest uncomformably upon them, all the Lower Carboniferous rocks being absent; but to the east they are cut off by the eastern boundary-fault of the coal-field. As has long been known, the rocks consist in ascending order of (1) Upper Llandovery Sandstone, (2) Barr Limestone, (3) Wenlock Shale, (4) Wenlock Limestone, which occurs in two bands separated by a mass of shales and nodular limestones.

The Upper Llandovery Sandstone was identified by Jukes[2] as cropping out at two localities along the eastern boundary-fault; first at Daffodilly, 2 miles east of Walsall, and secondly at Shustoke Lodge (now Shustoke Farm), Great Barr.

At Daffodilly, detailed mapping on the six-inch scale has led to an interpretation of the structure differing from that adopted by Jukes. A part only of the Barr Limestone comes to the surface, in a low anticline, its western margin falling into line with the general structure of the rest of the Silurian tract, while to the east it turns over and dips toward the adjacent Coal

[1] '*Midland Naturalist*,' vol. viii, 1885, p. 72.
[2] '**South Staffordshire Coalfield.**' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 109.

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Measures, from which it is separated by a fault. A sandstone which has hitherto been supposed to be of Upper Llandovery age has now been found to contain traces of plants and to be one of the Halesowen Sandstones (Newcastle Series), with the so-called Permian naturally superimposed upon it to the east.

At Shustoke Lodge, the rock, correctly identified as Upper Llandovery, is abundantly fossiliferous, and is faulted on the east against the 'Permian' of the Old Series Map; but instead of dipping westward or toward the Silurian shales on its western margin, as it was presumed to do by Jukes, it dips away from them and toward the boundary fault on the east, as was pointed out by John Jones in 1866.[1]

CARBONIFEROUS ROCKS OF THE SOUTH STAFFORDSHIRE COAL-FIELD.

The survey of the coalfield has been continued by Dr. Gibson and Mr. Cantrill. Mr. Cantrill notes that the gentle north-westerly rise of the coal-seams observable in the northern end of this coalfield is replaced some distance to the south by a rise in the opposite direction. As a result the principle seams crop out in the neighbourhood of Brownhills, and the Silurian floor comes to the surface near Walsall as described above.

In the Brownhills district the chief seams worked are the Yard, Bass, Cinder, Shallow and Deep Coals. These crop out alongside the eastern boundary-fault and range south-westward by Pelsall Common and Coal Pool to the Birchills near Walsall. Below the Deep or Bottom Coal, the Blue Flats, Silver Threads and Diamond ironstones have been worked by both shafts and crop-works, especially about Rushall Hall and church. These lowest Coal Measures rest upon various members of the Silurian Series, but the transgression is not very marked.

The eastern boundary-fault is shown on the old map as splitting into two branches at Chasetown. No serious modification has been found necessary in the position of the western branch, the Clayhanger Fault, and Jukes's interpretation of the ground along its eastern margin has proved substantially correct. The Eastern branch is however of a different nature, being a sharp easterly downfold rather than a clean break. It is within the tract between the two branches that the most important mining developments are taking place. At the surface there appear deep red marls containing occasional beds of angular breccia or 'Espley rock.' They are well exposed near Aldridge in a series of large openworks, excavated for the manufacture of blue bricks, and were correctly identified by Jukes as underlying the Halesowen Sandstones. Farther east, at Stonnall Hill, these Aldridge marls are terminated by a fault which brings them in contact with the red marls and clays formerly classed as 'Permian,' the outcrop of the Halesowen Sandstones being cut out. In a brook at King's Hayes Farm, Vigo, these so-called Permian marls contain a lenticular bed of Spirorbis limestone, and southward of Great Barr include impersistent bands of conglomerate, characterised by pebbles of red and yellow Carboniferous chert, with a small

[1] 'Notes on the Geology of the Midland Counties,' 8vo., Birm., p. 8.

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proportion of limestone, presumably Carboniferous also. There is no reason to doubt that they rest conformably on the Halesowen Sandstones, and are really of Carboniferous age, corresponding approximately to the Keele Series of North Staffordshire.

It may be noted that in the outcrop of Keele Beds at Stonnall Hill, a steep dip to the east appears, marking the oncoming of the fold described above.

WESTERN SIDE OF STAFFORDSHIRE COAL-FIELD.

The area between Great Wyrley and Willenhall examined by Dr. Gibson during the year chiefly lies north of the well-known Bentley faults which separate the region of the Thick Coal on the south from the region of the Pelsall, Wyrley and Essington Coals on the north.

He finds the chief interest lies in the western area situated between Holly Bank and Huntingdon, on the line of the so-called Western Boundary Fault. The fault is not evidenced at the surface within the Drift or Trias covered area, but has been proved by mining to consist of a belt of disturbed ground from one to two miles in width, in which several faults trending north and south let down the Coal Measures in the form of wedges. Though the aggregate downthrow of the faults is to the west this is partly counteracted by several considerable downthrows to the east and the increasing depths to the seams is largely due to their assuming a higher dip westwards.

THE CARBONIFEROUS ROCKS OF THE NORTH WARWICKSHIRE COAL-FIELD.

In the area about Whateley, Wood End and Kingsbury a fairly complete sequence has been determined by Mr. Barrow in the Carboniferous rocks, the information derived from numerous excavations having been supplemented by that derived from underground workings, which has been kindly supplied by Mr. G. Hurst of Kingsbury Colliery and by Mr. Allen of Hall End Colliery. The following divisions have thus been made out, in descending order:—

(1) Upper Red Marls and Sandstones. 'Permian' on old map.
(2) Upper Grey Measures. The Halesowen Sandstone Series.
(3) The Lower Red Marls and Espley-rocks.
(4) The Lower Grey Measures in which alone workable Coal-seams occur.

(4) Little new information has been obtained at the surface with respect to this part of the series. The fine section in the railway-cutting, referred to by Mr. Howell in his account of the district[1] is now greatly obscured. It may be worth recording that owing to the high dip on the east side of Dosthill the entire coal-bearing division crops out in a distance of about 400 yards.

(3) The Lower Red Marls at Whateley have a total thickness of about 200 feet. They are usually traversed by ramifying

[1] "Geology of the Warwickshire Coalfield" (*Mem. Geol. Surv.*), 1859, p. 25.

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cracks along which the colour has been leached out, and have thus acquired a distinct form of mottling. In the upper part of the brick-pit at Whateley Colliery, there is a conspicuous band of bright-green rock some 10 feet thick, almost entirely made up of angular chips of green shale, cemented by fine mud and carbonate of iron. The chips are often an inch across and show no trace of rounding. At its outcrop the bed has been weathered to a buff-colour and the identity of the chips with the Cambrian shales of Dosthill becomes obvious—another and closely similar bed at a lower horizon contains a more muddy matrix and far more carbonate of iron as cement, the undecomposed rock being nearly white. When exposed to the weather it falls into more or less rounded blocks with a brown ferruginous skin and shows the characters of an 'Espley rock.' Close examination shows further that the thick red marl-bands also contain vast numbers of shale-chips, in the form of small discs with perfectly rounded edges. These little chips may make up at least half of a band 10 feet or more thick, but their presence can only be ascertained by close inspection, for they are in most cases stained red, of the same tint as the enclosing marl.

In the green bands the angularity of the chips and their comparative freedom from interstitial mud shows that the material cannot have travelled far but that it must have originated as scree from a cliff. The Dosthill shales appear to have formed an island which must have survived as such till nearly the close of the deposition of these red marls; and we may infer from the thickness of the marls that it must have projected at least 800 feet above the general level of the old Carboniferous floor. To the south similar chip-beds are seen in the Cliff brick-pit but not beyond, owing to a fault; to the north, the proportion of chips in the marls steadily decreases. The same material, however, in a completely disintegrated form enters largely into the composition of the beds of this group still farther away, for at Glascote thick bands of fine buff mud occur in the red marls.

(2) The Upper Grey Measures (Halesowen Sandstone Series), which are about 400 feet thick, differ from the coal-bearing series in being paler in tint, and in containing a larger proportion of sandstone. In the lower part sandstones greatly preponderate; though variable they occur in three main beds. The rock, when fresh, is pale grey or white but it turns brownish on exposure. The highest bed can be recognised in that it is harder and of a distinctly brown colour even in shafts and borings. The upper 200 feet of the group consists mainly of singularly hard pale sandy clays or pale marls, with a few red bands in the higher beds. About the middle of the group is a bed of sandstone immediately under which lies the only persistent bed of Spirorbis limestone in the district. This, which may be called the Index-limestone, occurs about 60 feet above the brown sandstone mentioned above and about 140 feet below the base of the Upper Red marls; it is a compact, smooth-textured rock, and varies so far as is known from a foot to about 4 feet in thickness. An examination of the old marl pits left quite dry during the recent great drought has shown that Spirorbis limestones, in bands, or in

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lenticles or small nodules, are common in the upper part of the Halesowen Sandstone series, but the characteristic fossil is not abundant. In addition to the Index-limestone there is another band of a more crystalline character, that occurs some 100 feet higher up and is well-exposed in the mineral-railway from Kingsbury to Hall End Colliery, where it is 10 feet thick. This band was formerly mistaken for the Index-limestone.

(1) The Upper Red Marls and Sandstones form the 'Permian' of the Old Series map. They are exposed at the north end of the hill of Wood End in a new tramway and shaft and shown to consist of sandstones and marls, chiefly grey in the lower part but becoming increasingly red and more marly upwards. There is a perfect passage from the undoubted Carboniferous rocks (Halesowen Sandstones) upwards into this group, here as in the other Midland areas recently surveyed, and it follows that the lower part at least of the 'Permian' must be claimed as Carboniferous. Groups 1 and 2 correspond approximately to the Keele and Newcastle groups of North Staffordshire, but it must be understood that this remark at present applies only to the lowest 200 or 300 feet of the so-called Permian, the higher strata not having yet been examined.

RED ROCKS OF DOUBTFUL AGE.

In the Summary of Progress for 1910, p. 18, a brief description is given of certain beds, all more or less of a red colour, the age of which was still in doubt. It has now been found that between the South Staffordshire and Warwickshire Coalfields these beds fall into two divisions.

1. The Breccia-beds. The 'limestone-conglomerate' and associated breccias have been followed more or less continuously from Hopwas almost to the eastern margin of the South Staffordshire Coal-field. Though the abundant limestone-pebbles in it everywhere exhibit rounded outlines, the other pebbles are mostly angular or subangular. Where present the conglomerate always lies at the base of the Bunter Pebble-beds, and is associated with similar conglomerates or breccias which occur in a series of red-brown sandstones containing angular pebbles. The group generally forms a marked feature and has been recognised by Mr. Dixon in the Hints area, by Mr. Cunnington about Four Oaks and Streetly, and by Mr. Cantrill about Barr Beacon. There is no evidence of a strong unconformity between it and the overlying Bunter Pebble-beds, though the junction is irregular and suggestive of a slight break.

In North Staffordshire a 'limestone-conglomerate' which is precisely similar to and may be the same as that of Hopwas is exposed near the mouth of the Cheadle railway-tunnel, here also immediately underlying the Bunter Pebble-beds. But it is not known elsewhere in any part of the Cheadle district. Thus while it seems to adhere to the base of the Pebble-beds, wherever it has been met with, yet in much of the area it appears to be overlapped. That there is a great unconformity at its base is well

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shown at Cheadle, where these breccia-beds with abundant limestone-pebbles rest directly on the lower part of the Middle Coal Measures.

2. In the area south and south-west of Hints these breccia-beds rest on the upper part of the 'Permian,' which consists of a series of red marls and sandstones with occasional pebbly or conglomeratic bands, in one of which Mr. Dixon found a large fragment of Spirorbis limestone. The detailed mapping of the rocks visible at the surface does not suggest any great discordance between the breccia-beds and the 'Permian,' yet there must be one if we are right in believing that the breccia-beds rest on a far higher horizon in the 'Permian' in the Hints area than at Barr Beacon. Further, the higher 'Permian' beds of Walsall Wood and Stonnall on the eastern margin of the South Staffordshire Coalfield are affected by a steep and sudden easterly downfold, which has not involved some overlying breccias which we believe to be the quivalents of the breccia-beds of Hints. Mr. Barrow finds a similar sudden downfold on the opposite margin of this area, that is on the north-west edge of the known Warwickshire Coalfield. But in this case it takes place in at least two stages. The first stage has been proved in an adit by Mr. Grayston, at Amington Colliery, where by a combination of a fault and a high dip the coals are dropped to the north-west a distance of about 500 feet; the second is constituted by a fault which is known to run at a distance of about 400 yards to the north-west. It is gradually becoming clear that at the north end of the Warwickshire Coalfield, there is a sagging down of the Carboniferous rocks on a larger scale than in the ground a little further to the south.

The Streetly or Little Aston Boring.—This boring is situated in Roundabout Wood, close to the Midland Railway. It was put down to prove the depth to the workable Coal-seams and was carried to a depth of 1,907 feet but then abandoned. The following brief account has been drawn up by Mr. Cunnington; it is based on an examination of the cores, the greater part of which are still lying on the spot.

After traversing Pebble beds and a series of red sandstones with gravelly bands, possibly the equivalent of the Hopwas Breccia-beds—'Permian' rocks were reached at a depth of 77 feet from the surface. These comprise a series of marls, sandstones, and conglomerates, the general character of which did not vary much throughout the remaining 1,830 feet. No rocks resembling the Halesowen sandstones were met with, nor is there any record of a Spirorbis Limestone having been penetrated.

The sandstones are mostly of a dull-reddish colour frequently passing into green, and often containing spherical green 'fish-eyes.' In texture they vary from a fairly course to an extremely fine grain, thus seeming to merge into the marls with which they are interbedded. The coarser bands often contain pebbles which are sometimes so numerous that the rock may fairly be called a conglomerate. The greater proportion of the pebbles are green, pink or yellow cherts or cherty sandstones, but some consist of quartzite of the Bunter-pebble type, vein-quartz, and oolitic and

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porcellanous limestones similar to many Carboniferous limestones. Pellets of yellow and white clay occur together with marl-fragments of local origin. The majority of the pebbles are of foreign origin even in the lowest bands reached, and it is possibly legitimate to infer that the sandstones, which in Warwickshire contain only pebbles of local origin, lie below any rock reached in this boring. If this is correct, the first workable Coal would be nearly 3,000 feet down or possibly more.

At a depth of about 1,200 to 1,400 feet sandstone was traversed which was distinguished by a dull-brown colour passing into white, red, and purple.

Interbedded with the sandstones is a great amount of pink, red, and vermilion marl, usually too soft to yield a core.

The details of the boring are given below.

Streetly or Little Aston Boring.

(Abstract.)

One-inch map (New Series), 154. Six-inch Staffordshire, 64 N.W. About 450 feet above Ordnance Datum. Made in 1897 to 1904 by Messrs. Thom, of Manchester; details of the section communicated by Mr. L. Ridsdale, Streetly, Birmingham.

		Thickness. Ft.	In.	Depth. Ft.	In.
	Surface and sand	3	6	3	6
Pebble Beds.	Gravel with sand-bands	45	0	48	6
Breccia-beds.(?)	Gravel with sand and clay bands ...	28	6	77	0
	Red marl and sandy marl with thin sandstones	274	6	403	0
	Breccia	1	0	404	0
	Marl with thin red and green sandstones	162	0	566	0
	Conglomerate	25	0	591	0
	Sandy pink marl with red and green sandstone-bands	226	0	817	0
	Conglomerate with limestone pebbles ...	8	0	825	0
	Pink marl with thin sandstones	86	0	911	0
	Red sandstones with marl and conglomerate...	44	7	955	7
	Yellow, red, and purple sandstones with red marl conglomerate at base ...	287	0	1,243	2
'Permian' 1,830 ft.	Conglomerate	42	10	1,286	0
	Brown and red sandstones with thin conglomerates	101	4	1,387	4
	Very soft marl	48	0	1,428	0
	Sandstone with red sandy marl	77	0	1,505	0
	Marly red sandstone with calcareous breccia-bands	13	0	1,518	0
	Mottled red and green marl often sandy	90	0	1,608	0
	Sandstone passing into breccia	24	8	1,632	8
	Pink marl with sandstone-bands	45	2	1,677	10
	Pink marl with red and green sandstone and breccia	29	1	1,706	11
	Red marl and red and grey sandstone ...	139	9	1,846	8
	Conglomerate and bands of marl ...	24	6	1,871	2
	Red marl	36	10	1,907	0

TRIASSIC ROCKS.

Over much of the area surveyed during the past season portions of the Triassic rocks show the usual variation in composition and

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thickness. The most variable portion was penetrated in a boring for water at Maple Brook some three miles west of Lichfield. The cores were examined by Mr. Dixon, who divides the rocks as follows:—

Maple Brock boring.

		Feet.
Keuper Sandstone, with thin conglomerate at base		190
Bunter	Upper Mottled Sandstone	100
	Sandstone, with lines of pebbles in the lower part	325
	Conglomerate, penetrated to	18

The Keuper Sandstones are almost identical with those of the Bunter, but in this boring and some other places there is, at the base of the Keuper, a small band of conglomerate the matrix of which usually contains rather large grains and pebbles of unusually fresh felspar. In the absence of this band the boundary between the Keuper and the Bunter is frequently difficult to detect.

This Keuper conglomerate is well shown in a road-cutting at Hints; it is markedly false-bedded and contains fragments of the same quartzite as that of the Bunter pebbles, but while some are well rounded others are subangular. Two points of interest in this outcrop are the occurrence of pebbles of Carboniferous Limestone and the abundance of fresh felspar both in the matrix and as small pebbles.

At Hints there is only a small thickness of beds between it and the Bunter Conglomerate or Pebble-beds, though at Maple Brook some 400 feet of sandstones intervene.

The Bunter Conglomerate also varies considerably both in thickness and size of the pebbles contained in it. Mr. Dixon has found masses of pebbles at Freeford, to the south-east of Lichfield, while Mr. Cunnington observes that in the ground near Aldridge the conglomeratic bands are subordinate to the sandstones. Occasionally the pebbles may be as much as 12 inches in length; one specially interesting specimen of quartz-schorl rock was 14 inches long.

No undoubted Lower Mottled Sandstone has so far been met with in the area.

It may be here mentioned that *Estheria* has been found by Mr. Cantrill in a marl-parting in the Bunter; and by Mr. Cunnington in a marl-band in the Breccia-beds underlying the Bunter.

KEUPER MARLS.

A considerable area of Keuper Marls has been mapped by Mr. Cunnington between Tamworth and Lullington. The full thickness of the beds is not seen in this district; the highest beds occur about Haunton and Lullington, a boring at the latter place penetrating them to a depth of about 400 feet. Nearer the outcrop of the underlying sandstones a boring at Fradley reached the base of the marls at 178 feet and another at Elford failed to bottom them at 200 feet. Southward, nearer Tamworth, the lower beds only are exposed.

The marl is of the usual type and contains thin grey or slightly greenish, fine-grained sandstones (skerries) and bands of grey

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shale, especially near the base and in the neighbourhood of Tamworth. The skerries are seldom more than a foot thick and are frequently calcareous; while ripple-marks and casts of salt-crystals are often found on them. Though thin they are an important source of water-supply.

GLACIAL DEPOSITS.

The Western Drift.—The sheet of gravelly drift, referred to in last year's Summary of Progress as covering so much of the South Staffordshire Coal field, has been followed to the south by Dr. Gibson and found to occupy almost all the ground. In large excavations at Little Bloxwich, near North Walsall Station, and to the north and north-west of Pleck, it exhibits an upper member composed of an unstratified, frequently contorted, red sandy clay containing a few small far-travelled erratics interspersed among numerous Bunter pebbles. Though not usually more than 10 feet thick, it covers the greater part of the area. This is underlain by a lower member consisting of 50 to 70 feet of loosely stratified sands with lenticles of fine gravel. Neither drifts shew any tendency to an arrangement in mounds.

Mr. Cantrill also finds the sheet of Drift continuing southward to Walsall, until the higher Permian and Triassic borderland east of the Coalfield emerges from beneath it. At Walsall the sheet of gravelly boulder-clay ends abruptly in a long and lofty ridge of sand and gravel on which the older part of the town is built. A large gravel- and sand-pit at Ryecroft, on the northern outskirts of Walsall, shows a pebbly stiff sandy boulder-clay overlying and alternating with sands and gravels; but it has not been found practicable to map out the two types of drift in detail.

Boulders of far-travelled material have again to be recorded in the western part of the drift. Mr. Cunnington notes that the large boulders of felsite referred to in last year's Summary of Progress extend to the south of Barr Beacon and that boulders of white granite occur near Sutton. The eastward limit of distribution of these erratics may be roughly defined by a line trending from south to north from Barr Beacon, through Aldridge to Stonnall Hill; then turning by Shenstone to Lichfield; afterwards ranging nearly due west across the foot of the rising ground of Cannock Chase.

The Eastern Drift.—A considerable area of the flint-bearing or Eastern Drift has been mapped by Mr. Cunnington. After crossing the Tame about Tamhorn the western limit of this deposit trends in a north-westerly direction and crosses the Trent about King's Bromley.

LATE GLACIAL OR POST-GLACIAL.

Considerable numbers of Triassic pebbles of a characteristic 'dreikanter' shape have been found by Mr. Dixon in the neighbourhood of Lichfield. They appear to have acquired their form since their derivation from the Trias, posssibly in late-Glacial times, under conditions somewhat resembling those of the Loess period on the continent.

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3.—London and S.E. District.

Mr. Clement Reid, F.R.S., District Geologist.
Dr. R. L. Sherlock.
Mr. Henry Dewey.
Mr. C. N. Bromehead, B.A.
Mr. A. H. Noble, B.A.
} Geologists.

During 1911 the six-inch survey was carried eastward as far as Chesham, Pinner, and Richmond, and the Beaconsfield and Windsor one-inch maps are now complete.

This area may be described as the western part of the outer suburban belt which surrounds London. Its population is rapidly increasing, the country villages are growing into towns, and over most of it houses are springing up, or farms are changing into market gardens. The geology of this region is closely connected with the suitability of the land for these purposes. The area surveyed consists of Upper Cretaceous and Eocene strata and includes great part of the Chiltern Hills and the lower slopes of the Chalk from Rickmansworth and High Wycombe to Maidenhead. In the Tertiary basin we have mapped the Lower Eocene part between Maidenhead and Beaconsfield on the west and north and Windsor and Uxbridge on the south and east. This forms the comparatively low-lying or sloping ground on either side of the Thames. In addition, a large area of sandy strata (Bagshot, Bracklesham and Barton Beds) lying west of the Wey has been mapped. This includes the heath-lands of Ascot, Chobham and Bagshot.

As regards the unfinished Aylesbury map, it will be remembered that in the 'Geology of the Country around Henley-on-Thames,' Mr. Jukes-Browne mentions that the Upper Greensand is becoming more clayey at the northern boundary of the Henley map. Near Wendover Dr. Sherlock finds that the Upper Greensand has disappeared as a distinct division, so that it has been found necessary to map the Gault and Upper Greensand as one (Selbornian). The Selbornian passes upwards quite indefinitely, as far as lithological character goes, into Lower Chalk.

North-eastward to the northern margin of the Aylesbury map the same conditions prevail, and Mr. Reid was unable to find any trace of the Upper Greensand as a distinct division. There is neither a feature, such as even a thin sand-bed will form, nor do any springs flow or wells obtain their supply from this horizon, though springs are given out from several gritty beds in the Lower Chalk above. From the marly base of the Lower Chalk to the base of the Gault there is a continuous slope, becoming gentler and gentler till it merges into a flat.

The re-examination of the Aylesbury area failed to supply any corroboration of the faulted Gault, Lower Greensand, and Purbeck outlier shown on the old map. Mr. Reid found that the ferruginous loamy sand seen in the old pit is nothing but decalcified sandy Portland Beds, some of the harder ironstone masses still showing the oolitic grains. The shaly limestone with cyprids, formerly taken as evidence of Purbeck Beds, apparently comes below the bed of Portland building-stone, and fragments with these cyprids occur abundantly in the old stone-quarries,

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The supposed outlier of Gault was examined, and the very black soil near the high road was found to be the decayed remains of a quantity of Celtic black pottery, probably belonging to an ancient kiln.

In the escarpment of the Chiltern Hills the Lower Chalk is about 200 feet thick, and north of Tring it shows several bands of gritty chalk, which give out springs and form more or less conspicuous features. The shelf formed by the Melbourn Rock at the base of the Middle Chalk is more pronounced, though the rock itself is not here a well-defined lithological division. Southwestward Dr. Sherlock finds it to be less conspicuous. The Chalk Rock is the most clearly defined horizon in the Chalk, but it usually crops out on a steep slope down which clay-with-flints is continually being washed; it therefore does not make so noticeable a feature as would be expected. In the neighbourhood of Marlow it yields an exceptionally rich fauna, including the new ammonite *Desmoceras marlowense*, already described by Mr. Noble.[1]

The persistent bed of glauconitic greensand, mentioned in last year's Summary as forming the base of the Reading Beds, when traced eastward was found by Mr. Noble to be replaced by a thick pebble-bed. We are still unable to find any fossils in it, though the deposit is presumably marine.

Though Mr. Bromehead can trace in the Windsor map a sharply defined boundary between the London Clay and the Bagshot Sands, Mr. Dewey has been able to map out a considerable thickness of transition beds around Claygate, south of Surbiton. These ' Claygate Beds ' consist of alternations of even-bedded sands and clays; they are succeeded by strongly current-bedded sand of the normal Bagshot type.

Pebble-beds occur in the Bagshot, Bracklesham, and Barton Beds, and do not necessarily mark the base of any division. Mr. Bromehead finds that the Bagshot pebble-bed is about 10 feet above the London Clay and probably occurs throughout the Windsor area, though best seen in a section near Virginia Water station; the large pebbles in it are entirely flints. An impersistent pebble-bed is found at the top of the Bagshot Sand at St. Anne's Hill; at the Hatch pit it is represented by a few isolated pebbles only. The Bracklesham pebble-bed occurs 30 to 40 feet above the base, and is seen in the hills round Ottershaw and on St. Anne's Hill. As the reading of the section at the latter locality has been the subject of much dispute, it may be well to give that adopted as the result of the six-inch survey:—

	Plateau Gravel	A few inches.
Bracklesham 38 ft.	Pebble-bed	8 feet.
	Clays	30 ,,
Bagshot 140 ft.	Pebble-bed	2 ,,
	Sands, very loamy in parts	125 ,,
	Pebble bed	5 ,,
	Sands	10 ,,
London Clay.	Concealed by river drift.	

The Pebble-bed at the top is regarded as the equivalent of Dr. Irving's Bed 6, and not as the base of the Barton Series.

[1] *Geol. Mag.*, 1911, p. 398.

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Undoubted Barton Beds do however occur on St. George's Hill, on the south side of which a thickness of at least 50 feet has been mapped; but the basal pebble-bed is very poorly represented. At Stanner's Hill, near Chobham, where it is strongly represented, pebbles of chert occur, besides flints and quartz, a fact which may throw some light on the denudation of the Weald.

The Drift deposits examined during the past season were of exceptional interest; but it is useless to attempt to describe them till the new maps are available. An interesting example of stream-diversion, illustrated by a special map, is dealt with in the Appendix (p. 74).

(B.)—SCOTLAND.

The ground surveyed in the Highlands was arranged in two districts as follows:—

1. West Highland District, including Mull and South Morvern, under Mr. C. T. Clough, M.A.
2. North and Central Highland District, comprising parts of the counties of Sutherland, Perth, and Inverness, under Mr. L. W. Hinxman, B.A.

The Coalfield areas were grouped in two districts:—

3. Carluke, East Kilbride and Douglas District (Sheet 23), with a small part of Fifeshire (Sheet 31), under Mr. L. W. Hinxman, B.A.
4. Shotts and Fauldhouse District (Sheet 31), comprising also part of Ayrshire (Sheet 22), under Mr. C. T. Clough, M.A.

1.—West Highland District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. G. W. Lee, D.Sc.
Mr. J. E. Richey, B.A.I.
} Geologists.

The ground surveyed in this district lies in the Island of Mull and in South Morvern (Sheet 44, with small marginal areas in the adjoining Sheets 43 and 52).

METAMORPHIC ROCKS.

Morvern.—Dr. Lee finds that the Glass Bhein plateau is bordered eastwards by a strip of Moine Gneiss which in the region limited by the northern margin of the one-inch map 44 does not exceed two miles in width. The gneiss is throughout of the type described in last year's "Summary of Progress," p. 27, viz., a grey semipelitic rock with more siliceous bands and numerous foliated intrusions.

On the coast between Inninmore and Rudha an Ridire the strike of foliation is nearly north-east. Further north it gradually takes a more north and south course, and finally, near the northerly margin of Sheet 44, trends slightly west of north.

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NEWER GRANITES.

Morvern.—The area east of a line running from Loch Teàrnait to the mouth of the first stream flowing east of Rudha an Ridire is composed of a large mass of Newer Granite which spreads well into the unsurveyed country to the north. Dr Lee states that this granite is moderately coarse-grained, usually pink, less often grey, and is essentially composed of felspar, quartz and biotite, though it frequently contains hornblende also. The felspar exhibits a strong tendency to the development of a porphyritic habit, crystals one inch long being not uncommon. Mr. Bailey, who has seen this rock in the field, states that it has a marked resemblance to the Starav granite, which is later than the Lower Old Red Sandstone volcanic rocks of Glencoe.

This Morvern granite is traversed by a few dykes of salmon-coloured quartz-felsite unlike any Tertiary intrusive rock in this district.

The main junction line between the granite and the gneiss keeps a straight course, about 10° E. of S., from Loch Teàrnait, to the small loch east of Main a' Chullaich, while the rest of the boundary trends somewhat west of south.

The number of gneissic masses entangled in the granite varies to a great extent. Hardly any occur in the vicinity of Loch Teàrnait, while some two miles south of it they are so numerous that the boundary line becomes obscure. This belt of gneissic inclusions is, however, a narrow one, and in no place are they found more than about a mile within the granite boundary. They possess the same strike as the main mass of gneiss west of the granite, as if they were still in connection with the surrounding gneiss.

Small isolated veins and patches of granite and veins of pegmatite are found nearly a mile outside the main mass of granite. The pegmatites are obviously of the same origin as similar pegmatites which are common in the granite itself, near its margin, but practically absent from its centre.

The gneiss and granite areas are traversed by a large number of dykes. The presence of quartz-felsites has already been alluded to. Several of the dykes belong to the camptonite type, similar to intrusions in the gneisses of the Ross of Mull.[1] In both areas the trend of the dykes is roughly north-west, and as the Ross of Mull lies many miles south-west of Morvern, the dykes constitute two distinct belts. In the intervening country, composed mainly of Tertiary basalts, no such dykes have as yet been recognised.

TERTIARY ROCKS.

South of Loch Scridain (Mull).—The survey of the tract which lies to the south of Loch Scridain, begun by Mr. Lightfoot, was continued by Mr. Anderson. Westwards from Torrans the terrace features of the lavas become more and more marked. There is little sign in this ground of the general easterly dip

[1] 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 88.

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required by Prof. Judd's theory of subsidence; near Beach (one-inch map 43) indeed the flows dip plainly to the west. The lavas are basaltic, and generally contain olivine, which is visible in the hand-specimen. They are reddened on their upper surfaces, and often vesicular for half their thickness. There is no intercalated sediment, and rarely any tuff between the lavas.

Minor intrusions are extremely numerous. These mainly belong to one type, the olivine-free dolerites, or tholeiites referred to in last year's 'Summary of Progress,' by Mr. Lightfoot.[1] Often they form horizontal sills. As a whole the dip is to the south (though varying in steepness) with a persistent east and west strike. Perhaps three-quarters of them have pitchstone centres, in which 'sheath-and-core' structure is of frequent occurrence. Many of these tholeiites contain xenoliths. Sometimes these consist simply of baked sandstone, or of sandstone in which the quartz grains appear to have fused and run together. In other cases they are probably similar to the nodules consisting of bytownite and some ferromagnesian mineral, which have been described from Tràigh Bhàn an Sgoir, near Bunessan.[2]

A few examples of another type of intrusions occur which, with a somewhat similar groundmass, differ from the common type in containing numerous small phenocrysts of basic felspar. These intrusions also have pitchstone centres, which are porphyritic in the same way as the more crystalline parts. One of this latter class is cut by a non-porphyritic tholeiite in the bed of the Abhuinn nan Tòrr.

West end of Glen More (*Mull*).—Mr. Clough found that near Derrynaculen most of the lava flows contain abundant small phenocrysts of felspar, and vary in specific gravity between 2·80 and 2·90; olivine was not noticed megascopically. In a few places where the dip is clear it is eastwards, at about 15°, and it is considered probable that these porphyritic lavas are higher than those examined by Mr. Anderson in the country further west.

A little south of Derrynaculen a considerable band of fine-grained platy rock, resembling the mugearites, emerges from below the porphyritic lavas, but the top inclines rather steeply west and possibly the rock is of intrusive character. It is certainly older than a considerable mass of granophyre, and this in turn is earlier than a great number of inclined sheets of dolerite or gabbro.

These basic sheets usually incline eastwards at angles varying between 30° and 50°, and are frequently as much as 20 ft. or 30 ft. thick or even more. A good number are composite, being made up of various sub-parallel injections, the later with chilled margins against the earlier. Just east of Derrynaculen these inclined sheets are often equal in area to the slices of lava and granophyre which are preserved between them. A little further north-east is a large mass of gabbro which is tolerably free from later intrusions. The evidence so far collected favours the view

[1] p. 30.

[2] 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 92.

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that this mass of gabbro and most of the adjoining sheets of dolerite and gabbro are of much the same age, and represent different parts of one great intrusion.[1] Parts of the gabbro mass show a succession of thin bands of different tints[2] dependent on the proportions of the ferro-magnesian constituent, and these bands are frequently arranged in curves. It also includes a few masses of allivalite, one of which is at least 200 yards in length. The boundaries between gabbro and allivalite are never quite sharp, and in one of the best exposed junctions the gabbro is very rich in olivine and seems to pass gradually into allivalite. Parts of the allivalite display a prominent poikilitic structure, the spaces between the olivine grains being composed of felspar which has the same crystallographic orientation for a square inch or more. In one locality the allivalite contains various sub-parallel black streaks, sometimes an inch thick, which consist mainly of grains of black picotite.

It must not be supposed that all the gabbro in the district surveyed is so free from intrusions as that just north-east of Derrynaculen. On the hillside three-quarters of a mile south-south-west of Craig a great basic intrusion is composed partly of gabbro, in tolerably broad inclined sheets, and partly of an immense number of fine-grained inclined sheets, frequently only two or three feet thick, which are chilled against the gabbro or some adjoining fine-grained sheet. It is interesting to notice that in this locality even the coarse gabbro frequently contains rows of large amygdules.

Later than the basic inclined sheets are a number of thin sheets and dykes of more acid character, and a tolerably broad band of granophyre which has considerable resemblance to the greater mass of earlier granophyre already referred to.

The basaltic dykes in the district seem divisible into two sets, one striking almost north-north-west and the other nearly east and west. Both these cut the basic inclined sheets, but one dyke of the east-and-west set is seen to be cut in turn by an inclined sheet of sub-acid character.

South-east Part of Mull.—Mr. Bailey has continued his mapping in this complicated area, and has noticed two points of special interest. In previous Summaries a great breccia has been described resting in places on the eroded surface of a gabbro. The Tertiary age of this gabbro is now established since apophyses from it have been traced into the neighbouring lavas. The gabbro, however, is in the main associated with an extensive outcrop of Moine Gneiss, also described in former Summaries. A narrow band of tilted Mesozoic sediments has this year been found in the Abhuinn an t-Stratha Bhàin, one of the head waters

[1] This is also Prof. Judd's view. *Cf.* 'The Secondary Rocks of Scotland. Second Paper. On the Ancient Volcanoes of the Highlands and the Relation of their Products to the Mesozoic strata.' *Quart. Journ. Geol. Soc.*, vol. xxx, p. 243, and plate xxii, 1874.

[2] *Cf.* Sir A. Geikie and Dr. J. J. H. Teall, 'On the Banded Structure of some Tertiary Gabbros in the Isle of Skye.' *Quart. Journ. Geol. Soc.*, vol. 50, p. 645, 1894.

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of the River Forsa, separating the gneiss from the lavas on the north-east; it thus appears that the gneiss occupies the core of an anticlinal fold. The fold seems to have been extensively eroded before the formation of the breccia.

Salen District (*Mull*).—Along the coast north of Salen a gentle dip in the south-east direction brings successive lava flows to the surface at long intervals, each marked out by a reddened upper surface, invariably amygdaloidal, and frequently overlain by a layer of bole. The bole exposed at the side of a shallow estuary less than a mile south of Rudh' a' Ghlaisich is sometimes as much as four feet thick. Mr. Richey finds that it shows in places signs of stratification, but more generally the presence of bunches of amygdules in their natural position indicates that it represents a decomposed surface of lava.

A considerable mass of intrusive rock is well seen about four miles north-north-west of Salen, and extends for a mile along the coast, forming the promontories of Rudh' an t-Sean-Chaisteil and Rudh' a' Ghlaisich (Sheet 52). Under the microscope it is seen to be a coarse trachytic rock containing pseudomorphs which Mr. Thomas suggests probably represent nepheline. Inland this rock is bounded by lavas, the actual junction with which is only seen in the coast section on the south-west side of Rudh' a' Ghlaisich. It is characterised by platy joints which in most places keep varying in inclination rapidly. Within a distance of 80 yards from the lavas they always incline steeply away from the line of junction, but at a distance of a foot or so they are lost, and the trachyte presents a chilled outer edge to a narrow lenticular mass of agglomerate that lies between it and the lavas. Here the two junctions—between trachyte and agglomerate on the one hand, and agglomerate and lavas on the other—appear to be vertical. The agglomerate, which is nowhere else exposed, contains sub-angular blocks of basalt, up to four feet in length, as well as a mass of red bole. From this point the boundary line runs inland for a little space, but it curves round and reaches the sea again about half a mile west-north-west of Rudh' an t-Sean-Chaisteil. The junction here is not exposed but is doubtless vertical, as its outcrop keeps straight from cliff summit to shore.

The trachyte is certainly intruded through the lavas, and the presence of the agglomerate suggests that it is part of an old volcanic vent.

A number of north-north-west basic dykes cut the trachyte, and two of them cross the junction of the agglomerate and lava.

Morvern.—Several dykes appear undistinguishable from the common basaltic type seen in the Glais Bheinn plateau, and are consequently considered to be of Tertiary age.

Both the basaltic and the other dykes have the same general direction. In the southern half of the ground they run predominantly north-west, but further to the north their course is much more westerly. This applies also to the faults, of which there are a large number, all playing a conspicuous part in determining the direction of the streams.

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PLEISTOCENE AND RECENT.

West end of Glen More.—The 100-foot raised beach which was noticed last year at Kinloch by Mr. Lightfoot[1] does not appear to extend so far up the glen as Derrynaculen, though parts of the valley floor lie below the 100-foot contour. The valley floor in this locality is wide and composed to a large extent of rock, or of rock with a thin cover of peat. Glacial striae are abundant on the hill slopes and indicate a general westerly ice movement.

Morvern.—In the area surveyed by Dr. Lee hardly any drift is seen, but erratic boulders of local rocks are of common occurrence. Boulders of white quartzite and of Lismore Limestone have been found on the summit of An Sleaghach, 1,685 feet—the highest hill in South Morvern. This is in harmony with the westerly ice-flow indicated by striæ detected at a few points.

Raised beaches—of which only the 25-foot beach is well marked—are restricted to a few localities. Indications of the 50-foot beach occur at Glensanda.

2.—North and Central Highland District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. M. Macgregor, M.A., B.Sc. } Geologists.
Mr. C. H. Dinham, B.A.

Field-work was carried on during the past season in East Sutherland by Dr. Crampton in the Ben Armine Forest (Sheet 109); by Mr. Macgregor in the same district and to the north of Loch Shin (Sheet 108); and by Mr. Dinham in Glen Cassley (Sheet 102). In Inverness-shire and Argyllshire the survey of Sheets 54 and 63 was continued by Mr. Hinxman in the Corrour Forest and by Mr. Macgregor in the ground to the south of Loch Bà.

Mr. Carruthers was engaged during the whole year in the preparation of a new edition of the Survey Memoir on the Oil Shales of the Lothians, and was unable to take part in the field-work in the Highlands.

East Sutherland.

Highland Metamorphic and Associated Igneous Rocks.

The rocks of Lewisian type in the Ben Armine district (Sheet 109) referred to in last year's Summary of Progress (p. 41) have been found by Dr. Crampton to extend over an oval-shaped area of the peat-covered plateau to the east of that mountain. They are chiefly biotite-gneisses with biotite-hornblende-gneisses and some bands of hornblende-gneiss; some of them appear to be synthetic gneisses built up from sediments by alternate phases of acid and basic igneous intrusion, dynamical metamorphism, and later igneous impregnation. They can usually be separated from

[1] 'Summary of Progress' for 1910 (*Mem. Geol. Surv.*), 1911, p. 39.

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the rocks of the neighbouring Strath Halladale complex, which are proved by their field-relations to be pelitic and siliceous schists of the Moine Series impregnated with post-foliation granitic material. The main points of difference are the greater abundance of hornblende-bearing gneisses and the more intense and uniform granitization of the rocks of Lewisian facies.

The effect of the granite-impregnation in the Strath Halladale complex on some of the hornblende-schists and pelitic gneisses of the Moine Series has been to convert the former into hornblende-gneisses and the latter into massive biotite-gneiss, both indistinguishable in the field from those of the Lewisian type. The last named have a general N.W.-S.E. strike and appear to be folded along an anticlinal axis, the western limb of the fold dipping west beneath the rocks that form the main mass of Ben Armine. Their junction with the latter generally gives rise to a marked feature, which extends more or less horizontally along the eastern slope of the mountain.

The rocks which overlie this feature consist of a massive gneiss with characters proving it to be a pelitic gneiss which has undergone varying degrees of granitization. Similar rocks in the surrounding districts have been traced along the strike into the typical unaltered pelitic gneiss of the Moine Series, interfolded with siliceous schists of the same series.

The strike of the pelitic gneiss overlying the feature is approximately at right angles to that of the rocks of Lewisian type beneath, and the two are separated for a long distance by an irregular sill of granite which has its chief development toward the northern end of the mountain-ridge.

The boundary of the rocks of Lewisian type forming the plateau to the east is somewhat obscured by peat and drift, but the higher ground along its eastern limit is formed of pelitic and siliceous schists of the Moine Series, some unaltered, and some showing various degrees of granitization. These schists have the N.E. and S.W. strike of the pelitic gneiss of Ben Armine, at right angles, as already stated, to that of the rocks of Lewisian type.

Wherever the junction between the Moine and Lewisian type of rocks has been observed, either on Ben Armine or further to the east, the beds immediately underlying the line of separation consist of rapidly alternating biotite- and hornblende-gneisses of a peculiar platy nature, and with a very low angle of dip.

The further examination by Dr. Crampton of the rocks of the Strath Halladale complex confirms the opinion, expressed by him in former Summaries, that the various synthetic gneisses, even those which have all the appearance of foliated granites, have been produced by the impregnation of the pelitic and siliceous schists of the Moine Series with granitic material, subsequently to the regional dynamical metamorphism.

The strong resemblance of many of the rocks of Lewisian type in this district to these granitized Moine Schists, further suggests that the former may have acquired their present condition through a similar process; that they were originally sediments

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which have been subjected, in a still greater degree, to igneous intrusions and especially to those of a basic character.

The field-evidence, though pointing strongly to a discordance between the rocks of Lewisian type and those of the Strath Halladale complex, is insufficient at present to prove that the granitization of the former is of older date than that of the latter.

The result of the mapping of the southern extremity of the Ben Armine ridge by Mr. Macgregor is in accordance with many of the observations recorded by Dr. Crampton. Mr. Macgregor also recognises two sets of rocks of entirely different facies, and with a different strike, separated by a well-marked line of discordance. Below this line the rocks are predominantly of Lewisian type, being banded acid and basic gneisses with a remarkably even foliation, but with these occur certain rocks which in their granulitic texture approximate to the Moine type: above it come contorted garnetiferous mica-schists of pelitic Moine type.

The exact nature of the line of discordance referred to above has not yet been determined; it may possibly represent an unconformable junction masked by subsequent folding and foliation. At one point, the occurrence of isolated fragments of hornblendic rock in the pelitic schist, just above the junction line, suggests a possible conglomerate. The granite sill which, as already stated, follows the line of junction for some distance, serves further to obscure its exact significance.

Gneisses of Lewisian type also occupy the two small areas surveyed by Mr. Macgregor in Sheet 108. An altered peridotite, found at the head of Strath na Sealga, may be connected with the mass of similar ultra-basic rock on the south-east side of Loch Coir an Fhearna, six miles to the north-west.

Sillimanite-gneiss was also met with in the Strath na Sealga area. The sillimanite occurs in large fibrous bundles in a highly metamorphosed pelitic rock, and is possibly a result of the thermo-metamorphism caused by the neighbouring later granite intrusions.

The ground mapped by Mr. Dinham in Glen Cassley lies wholly within the Moine Schist area, and is chiefly occupied by massive quartzo-felspathic gneisses with little or no biotite, in which the dominant divisional lines are those due to jointing.

In the extreme west of the area, approaching the Moine thrust plane, the massive rocks are gradually succeeded by schists of a well-marked flaggy type distinguished by a considerable development of biotite, and also fairly rich in muscovite. These rocks resemble generally the flagstones of the Oykell Bridge section, 7 miles to the south.

Throughout the area mapped there is a marked absence of igneous rocks; only one small intrusion of a coarse hornblende-felspar rock having been observed.

Glacial.

That the eastern corries of Ben Armine at one time nurtured their independent glaciers is proved by the fine example of a

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crescent-form terminal moraine that rests on the plateau at the mouth of the corrie under Creag Mhor.

The retreat moraines of the Glen Cassley glacier are especially well developed immediately south-east of Duchally, where at their lower limit they pass insensibly into well-defined river terraces. The striæ observed on the watershed between the Cassley and Loch Shin indicate an outward radiation of the ice from the mountain mass of Ben More Assynt and a movement across the watershed into the Shin basin.

Peat Mosses.

At several points in Sheets 108 and 109, in the Ben Armine Forest, good sections of the peat are exposed in which a layer containing sub-arctic plants was found immediately overlying the boulder-clay. The peat above contains generally the remains of two forest growths; the lower of birch, the upper of pine, separated by one to three feet of peat composed chiefly of *Eriophorum* and mosses. No trace of a higher arctic bed was met with.

Perthshire and Inverness-shire.

Metamorphic Rocks.

In Sheets 54 and 63 Mr. Hinxman has traced the Moor of Rannoch granite northwards through the Corrour Forest across the margin of Sheet 54 at Loch Guilbhinn. The rock presents the usual characters of the Moor of Rannoch intrusions; it is in contact with pelitic and siliceous schists of Moine type, and the junction, where visible, is of the usual complex nature. The granite contains later intrusions of more acid rock, while both are cut by the porphyrite dykes which are numerous in the region.

The granite area mapped by Mr. Macgregor south of Loch Bà is also of the usual type containing both hornblende and biotite, with local variations in texture and composition.

Glacial and Recent.

The position and present direction of outflow of Loch Ossian in the Corrour Forest afford a good example of the modification of a drainage system by glacial action.

This loch occupies a hollow, partly a rock basin, in the lower part of a straight valley, developed along a line of fault, and running south-west towards Loch Treig. The upper part of the valley is drained by the Uisge Labhair, but this stream, half a mile before reaching the foot of the loch, turns suddenly at right angles and flows northwards through Strath Ossian to the Spean.

A consideration of levels and other evidence shows that a lobe of ice from the Moor of Rannoch *mer de glace*, passing eastwards and northwards through Strath Ossian, over-deepened the head of that valley and caused the sudden divergence of the Uisge Labhair from its former direct south-west course through the

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valley now occupied by Loch Ossian. The eastward moving ice at the same time eroded the valley floor at the point of greatest constriction, about half-way down the loch, to a depth of at least 100 feet, and further, in its retreat, laid down the barriers of morainic drift which now, to a certain extent, hold up the waters of the loch at either end. That Loch Ossian now drains to the north-east is a mere accident, and due to the barrier at this end of the loch being lower and more easily cut through than that at the western extremity.

3.—Carluke, East Kilbride and Douglas District (with a part of Fife).

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. R. G. Carruthers.
Mr. M. Macgregor, M.A., B.Sc.
Mr. C. H. Dinham, B.A.
} Geologists.

This District includes a small area in Fife which was examined by Dr. Crampton, who also obtained further mining information from Carron, Banknock and Kilsyth, in areas of which the surface geology had already been surveyed.

Revision of the coalfields in the Wishaw district was continued by Mr. Macgregor, and in that of Larkhall and Stonehouse by Mr. Dinham. The examination of the Auchenheath area was commenced by Mr. Hinxman. While preparing the new edition of the Oil Shales Memoir Mr. Carruthers procured a large amount of new information with regard to recent developments in the oil-shale industry of the Lothians.

Carboniferous Limestone Series and Millstone Grit.

Culross, Fife.—In the Fife coast area, Dr. Crampton had opportunities of examining good natural sections of parts of the Upper Limestone Group and Millstone Grit; he also obtained many bore-sections, some of which show the strata to a depth below the Dunfermline Splint Coal. These bores indicate that the thickness of the Carboniferous Limestone Series in this part of Fife is greater than in any part of the Lothians or of the Lanarkshire basin, the beds thinning to the west in the direction of Bannockburn, Plean and Denny, and to the south towards the Lothians.

The Edge Coals are wrought in deep pits at Valleyfield, on the coast east of Culross, and further inland at Blairhall. A thick mass of black blaes with ironstone bands that occurs about 150 fathoms below the Index Limestone and 80 fathoms above the Dunfermline Splint Coal in all probability represents the important horizon of the "Black Metals" of the Denny, Kilsyth and Glasgow districts. If this assumption is correct, the Lochgelly Splint is on the same horizon as the Bannockburn Main Coal and the Cloven Coal of Kilsyth.

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In the strata below the "Black Metals" there is a much greater development of coals in the Fife area than in Stirlingshire. The Kilsyth Coking Coal probably lies at a horizon considerably higher than that of the Dunfermline Splint, since the latter is within a comparatively short distance of the Top Hosie Limestone whereas the Kilsyth Coking Coal lies more than 60 fathoms above that limestone and comparatively close to the "Black Metals."

The limestones of the Upper Limestone Group are easily recognisable in this part of Fife. The Calmy Limestone is well developed and is underlain by a thick coal, the "Janet Peat"; the Index Limestone is usually four to five feet thick. One or two thin marine limestones are also met with between the Calmy and Castlecary positions.

The Castlecary Limestone, where exposed in a quarry near the shore at Culross, consists of two portions; the upper contains fish and plant remains and is apparently of fresh or brackish-water origin; the lower is an encrinital marine limestone with the usual pale colour and semi-crystalline texture of the Castlecary rock.

The section in the Cavieburn Quarry is as follows:—

	Ft.	In.
Yellow and white sandstone; grain very fine and well rounded.		
Alum shale	1	6
Limy ironstone	0	4
Hard, dark cement limestone with fish scales, coprolites and plant remains	3	6
Alumy shales with fragments derived from the underlying limestone	0	9
Pale encrinital limestone ... ... at least (formerly worked by a mine)	5	0

The cement limestone occupies the same horizon as the oil-shale which overlies the Castlecary seam in the north-west of Fife, at Levenseat and elsewhere, and thus indicates a widespread change from marine to land or brackish-water conditions at the commencement of the Millstone Grit Period.

Further sections show a calcareous band higher in the sequence, followed by a thick fireclay which may possibly represent the Lower Fireclay of the Glenboig district.

The Millstone Grit contains numerous bands full of angular quartz fragments up to one inch in diameter; a few small pebbles of granite have also been detected. Plant remains are common; the fireclays are sometimes full of *Stigmaria* rootlets, still attached to the roots. In such cases there is therefore no reason to believe that the fireclays were formed otherwise than those of the Coal Measures.

The sandstones and fireclays are remarkably lenticular in character, and the former often show current-bedding and crumpling of the original planes of deposit. The crumpled beds frequently include thin lenticular layers of bright coal formed from the bark of tree-trunks lying in a more or less horizontal position, and with the external ornament still preserved. The sections suggest that the deposits were disturbed by the decay of the

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wood and consequent collapse of the buried tree-trunks. The bright and highly inflammable coal of these layers contrasts strongly with the papery coals interleaved with shales which often underlie the lower limestones of the Douglas district in Lanarkshire; and consist chiefly of fragments of carbonised wood, being evidently formed from drifted material.

This difference tends to support Mr. Pringle's[1] views as to the origin of the bright and dull layers in coal seams, since the bright coal is found under conditions that suggest its formation by the removal of the woody material from tree trunks already deposited; whereas the dull layers occur in a manner that points to their being entirely made up of material transported from a distance.

Auchenheath.—The area revised by Mr. Hinxman between the Clyde at Crossford and the Nethan north of Lesmahagow forms a part of the most southerly extension of the Lanarkshire basin, in which the Carboniferous Limestone and Calciferous Sandstone rocks appear from beneath the coalfields of Stonehouse and Dalserf. Along the southern boundary these strata have been laid down upon an extremely uneven surface of the older rocks, the amount of overlap being indicated by the fact that between the Nethan and Hallhill, a distance of 1½ miles, beds from a short distance below the Main Limestone up to those about the horizon of the Gas Coal are found resting in turn upon sedimentary and igneous rocks of Lower Old Red Sandstone age.

Three main faults cross the area from north-west to south-east, with the effect that immediately south of Craignethan Castle a raised fault-block of the Lower Limestone Group of the Carboniferous Limestone Series is in contact to the north with the Middle Coal and Ironstone Group of the same Series, and to the south with beds ranging from the base of the Coal Measures to the Upper Limestones.

The course of these faults, and of the many minor dislocations with which the field is troubled can be followed in the workings of the Gas Coals, which were at one time extensively wrought in the country between Lesmahagow and Crossford, while the gorges of the river Nethan afford good natural sections of the strata below the Gair Limestone.

The principal horizons in the Carboniferous Limestone Series, from the Gair or Calmy down to the Main Limestone, are clearly recognisable in the Auchenheath district, though the Gair and Gillfoot seams of the Upper Limestone Group have to a large degree lost their normal "calmy" or argillaceous character.

The thickness of the intervening strata has however diminished considerably from that found to the east and north-east, on the other side of the Clyde valley. This is particularly the case with the Upper Limestone Group, the distance between the Gair and the Index Limestones decreasing from 65-70 fathoms at Wilsontown and Carluke to 34 fathoms at Auchenheath.

[1] 'On the Origin of Bright Laminæ in Coal, and a Suggestion arising out of their Distribution.' Read before the Edin. Geol. Soc., January, 1911, but not yet published.

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The base lines of the Millstone Grit and Coal Measures have yet to be determined; from the evidence already obtained it seems probable that the Millstone Grit is also much attenuated in this region.

Coal Measures.

Wishaw District.—The examination of the excellent section of the Coal Measures displayed in the Garrion Burn, near Law Junction, has now been completed by Mr. Macgregor.

With the exception of portions of the strata between the Splint and Virtuewell Coals, a fairly continuous section is exposed from the Kiltongue Coal to a position about 53 fathoms above the Ell Coal. The chief horizons actually seen are—the Kiltongue Coal, the Kiltongue Musselband, the Ladygrange and Virtuewell Coals, the Musselband Coal position, the Humph position, Main and Pyotshaw Coals; and the probable equivalents of the Upper Coal and Palacecraig Ironstone.

The positions of the Splint and Ell seams are given by day-levels;—some of the crop workings along this stream go back for more than a hundred years. The Ell, Main and Splint were thick and very valuable seams, but are now almost exhausted. The Main can, however, still be seen in two natural sections. The Pyotshaw, 5 to 5½ fathoms above the Main is about 13 inches in thickness, the probable representative of the Humph only 2 inches, but both these seams thicken towards the east, and the former is wrought at Straven Colliery.

A noteworthy point in this section is the occurrence of "mussels (*Carbonicola*, *&c.*) at eight different horizons, as indicated in the table given below. The horizon beneath the Ell Coal occurs also in the Rutherglen district and many other places; that below the Main has not been recorded so often, but is known at Bellshill and Rawyards. Except in the case of the Kiltongue Musselband and the 11-inch "Mussel-ironstone" 29 fathoms above the Ell Coal, "mussels" are not abundant at any of the horizons mentioned.

The section of the Kiltongue Musselband in the Garrion Burn is as follows:—

Sandstone, thick.

	Ft.	In.
Blaes	1	4
Parrotty Oil Shale	0	4
Musselband	0	8
Ironstone, clayband	0	2

Fireclay.

At two points in the section a few inches of white clay, overlying thin seams of burnt coal, represent the dolerite intrusions that are found in the Law and Shawfield coalfield. These intrusions take the form of thin "whin floats" and occur at different levels, generally overlying coal seams, and are connected by nearly vertical dykes.

In Straven Colliery the Pyotshaw Coal has a roof of "white trap," and in the Brownlee workings the Kiltongue is locally covered by an 8- to 12-inch sill, by which the coal is burnt for about six inches.

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Summarised Section of the Garrion Burn.

	Fms.	Ft.	In.
Strata, chiefly sandstone and fakes, with two gaps	17	3	11
Blaes and ironstone ribs with "mussels" ...		1	0
Blaes		2	0
Blaes and ironstone ribs with "mussels" ...		1	1
Strata		3	1
Coal		0	8
Strata	1	3	5
Coal		0	8½
Strata	2	5	10
(Possible gap)			
Strata (with several ironstone ribs) ...	1	0	3½
Faky Musselband Ironstone (Palacecraig position?) overlying 2- to 4-in. coal		0	11
Strata	1	1	8½
Upper? Coal with soft bands		3	5½
Strata ... ... 4⅙ fms. to	4	5	0
Coal with fireclay parting...		1	9
Strata (about)	22	0	0
Ell Coal	1	3	4
Strata	5	4	7
Shaly blaes with a few "mussels"		0	7
Strata	1	3	0
Pyotshaw? Coal, "white trap" above locally ...		1	0
Strata	1	5	9
Coal, burnt, with "white trap" above ...		0	11
Strata	3	5	9
Main Coal...		5	5
Strata	2	2	5
Coal		0	5
Strata	3	5	0
Cannel shale with some "mussels"		0	11
Strata—including Humph Coal Position ...	8	0	3
Splint Coal	1	0	0
Gap (possibly)	2	0	0
Strata—sandstone	2	3	0
Musselband			
Blaes and ironstone balls	4	1	8
Coal		0	3-5
Blaes and balls and kingley sandstone ...	1	2	6½
Mussel band		0	7
Blaes and ironstone ribs	0	3	1
Coal		0	3
Strata		5	10½
Possible Gap (Fault here)	3	0	0
Airdrie Blackband Coal position?		1	9
Strata	7	3	0
Ironstone } from bores (up to)		0	6
Strata	3	3	0
Virtuewell Coal		3	11½
Strata	4	5	2½
Ironstone with some "mussels"...		0	2½
Strata	4	0	0
Parrot shale and "mussels"		0	4
Fireclay		0	11
Ladygrange Parrot Coal		0	7½
Strata	11	0	8
Kiltongue Musselband		0	8
Strata (about)...	7	3	0
Kiltongue Coal		3	4

In the area between Stonehouse and Larkhall, examined by Mr. Dinham, the principal coal seams of economic value are the

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Virtuewell, Kiltongue, and Upper and Lower Drumgray. The Kiltongue Coal is often in two leaves, separated by six inches of fakes or fireclay. Between the Kiltongue and the Upper Drumgray there occurs a thin seam, locally known as the Jewel, which in a very few places reaches a workable thickness of 2 feet. The Upper and Lower Drumgray in this district are usually close together, and rarely more than 10 fathoms below the Kiltongue. From 4 to 8 fathoms below the Lower Drumgray lies the Watstone Musselband Ironstone, associated with a thin parrot coal. Below this horizon the strata are variable and but imperfectly known; in the eastern part of the area a few thin coals occur here and there within a considerable thickness of sandstone and fakes; in the western portion one or more ironstones, locally known as slatybands, have been wrought to a small extent in former times.

The base line of the Coal Measures in this district is as yet undefined.

Economics.

Coals and Ironstones.

Carboniferous Limestone Series.—The well-known Lesmahagow Gas Coal, which lies at an average depth of 33 fathoms below the Index Limestone, and the "Wee" Gas or Auchenheath Oil Coal, 15-19 fathoms higher in the series, were extensively wrought during the last century in the Auchenheath district.

Over the greater part of the field these seams are practically exhausted, and as there is now no demand for cannel coal for gas-making the Gas Coal industry in this part of the country may be regarded as extinct.

The only coals now wrought in the Auchenheath area are the Smithy, a 17-inch seam 14-16 fathoms below the Index Limestone, and the Dross (locally known as the "Lime") Coal, 6-7 fathoms lower down.

The Smithy coal, which is locally burnt by a thin 'whin float,' is raised as a house and steam coal from a mine on the Nethan near Auchenheath Station.

The Dross Coal is mined and used for burning the limestone at the Netherton Lime Works, south of Auchenheath.

At the Valleyfield Pits, Culross, Fife, the 5-feet and Dunfermline Splint Coals are now being raised. The former is often as much as 6 feet thick, the latter, which is worked at a depth of 210 fathoms, is 3 to 4 feet in thickness. Both are used as steam navigation coals.

Coal Measures.—Mr. Macgregor reports that in the Wishaw and Morningside district mining is now practically confined to the Virtuewell, Kiltongue and Lower Drumgray seams—all house coals.

The thick upper seams are practically exhausted, though the Ell and Splint Coals are still worked to a very small extent respectively at Woodhall Colliery, Cambusnethan, and at Shawfield.

The Pyotshaw—a furnace coal—is wrought by coal cutters at Straven; the Virtuewell and Kiltongue are largely raised at

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Garriongill and Brownlee; the Lower Drumgray at Herdshill, and all three seams, together with the Upper Drumgray, are or have lately been worked at Chapel Colliery.

Of the seams below the Lower Drumgray, the Mill Coal is probably the only one of much value, and may average 1 foot 10 inches in thickness; the other Armadale coals are thin.

No ironstones are now worked in this area, but the fireclay beneath the Lower Drumgray Coal is locally mined.

In the Stonehouse and Larkhall area Mr. Dinham finds that the Virtuewell, Kiltongue, and Upper and Lower Drumgray are raised as house coals of varying quality. In the neighbourhood of Swinhill all these seams with the exception of the Upper Drumgray have at different times been coked, but the coking character is only local.

The Watstone Musselband Ironstone was at one time wrought at Watstone and elsewhere in the parish of Stonehouse.

Building Stone.

A fine-grained white freestone or "liver rock" is now being quarried by the Clydesdale Brick and Quarry Coy. at Auchenheath, and affords a building stone of high class quality which has been used in churches, schools and other public buildings in Glasgow and many other places. The sandstone lies a short distance below the Gair or Calmy Limestone, from which it is separated by thin blaes and about 12 feet of ganister; the latter is about to be used in the manufacture of silica brick. The freestone forms a bed about 30 feet in thickness, resting upon a coarser rock, the total thickness of sandstone in the quarry amounting to over 50 feet.

A thick freestone on the same horizon was formerly wrought at Threipwood, near Crossford, but abandoned owing to difficulty of carriage.

The sandstones of the Millstone Grit are wrought in Longgannet Quarry, on the Fife Coast near Culross. The stone is of very unequal quality, some of the beds being very soft. It is at present supplying material for the Methil Docks; the soft material is put through a Baxter crusher to provide sand for cement. Stone from this Quarry was used in the docks at Grangemouth.

Road Metal.—A very hard, compact, red felsite, intrusive in the Lower Old Red Sandstone, is quarried at Hazelbank and affords excellent material for road metal. A similar rock from the Dunduff Quarries, Lesmahagow, is used in the Larkhall district.

Bricks and Tiles.—At the Milton Brickworks, Carluke, Messrs. R. and J. Gibson manufacture ordinary bricks of ground blaes from the adjacent old ironstone workings; also clay bricks from a deposit of brown laminated plastic clay, 20-30 feet in depth, which appears to occupy a hollow in the boulder clay.

Draining tiles are made at the Auchenheath Tileworks from a similar deposit of laminated clay. The clay is stoneless, but contains a few calcareous concretions.

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4.—Shotts and Fauldhouse District (with part of Ayrshire).

Mr. C. T. Clough, M.A. District Geologist.
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. B. Lightfoot, B.A.
Mr. J. E. Richey, B.A.I.
Mr. G. V. Wilson, B.Sc. } Geologists.

In continuation of the work of preceding years, the revision was carried on in Sheet 31 and portions of Sheets 23 and 39 which immediately adjoin the former. A beginning was also made with the revision of Sheet 22.

Calciferous Sandstone Series, Carboniferous Limestone Series, Millstone Grit and associated Volcanic Rocks.

Wilsontown.—The area on the south side of the big east-and-west fault which passes a little south of Hendrey's Course has lately been re-examined by Mr. R. G. Carruthers and Mr. B. Lightfoot, and it is clear that the bands of limestone and encrinital shale which outcrop near the head of the burn about half a mile south-west of the Ordnance Station 1197 do not occupy the crest of an anticline as formerly stated,[1] but are lying almost horizontally over the shales and thin ironstones—Raesgill Ironstones—which occur a little lower down the burn. The limestone and encrinital shale no doubt belong to the Main Hosie Limestone. As we proceed further up the stream, the strata rise to the north-east, and the shales and Raesgill Ironstones emerge again and occupy the bed of the stream until the east-and-west fault is reached.

Saltcoats and Ardrossan.—The section south of the old dock at Ardrossan is somewhat obscure, Mr. Anderson states, but seems to indicate that a series of sandstones and cornstones immediately underlies the Calciferous Sandstone volcanic series, and that the Cementstone Group as such is absent in this district. A little further east the top of the volcanic series is seen to underlie two dark grey limestones, occurring in association with hard calcareous sandstones.

The interesting section in the cutting of the Caledonian Railway north of Saltcoats shows the most westerly exposure, on the mainland, of the volcanic horizon in the Millstone Grit.

Auchenskeith.—Mr. Wilson gives the following details of the section in the Lower Limestone Group at Auchenskeith Quarry:—

		Ft.	In.
	Limestone and shales full of *Productus* towards the top, and near the bottom packed with zaphrentids	28	0
	Calcareous shale and 'alum shale.'	2	0
	Pyritous coal	0	6½
	Limy fireclay with nodular base	5	6
	Shale	2	0
Limestone.	Very hard fine-grained...	0	8
	Hard crystalline, at least	5	0

[1] 'The Geology of the Neighbourhood of Edinburgh,' 2nd Edition (*Mem. Geol. Surv.*), 1910, p. 106.

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Mr. Carruthers believes that the bottom limestone may represent the Blackbyre Limestone and the top limestone the Hurlet Limestone. In last year's Summary of Progress (p. 52) he correlated the Lower Limestones at East Kilbride with those of Hurlet, but noted the entire absence of the Hurlet Coal in the first-mentioned locality. It is therefore rather interesting to find the coal taking its place in the Ayrshire sequence, and although in the quarry it is only 6½ ins. thick, in a bore less than a mile away it is 1 ft. 3 ins.

A coal 8 fms. below the Index Limestone (the Highfield Limestone of Ayrshire) has been worked on a small scale and is locally known as the Lylestone Main. It is sometimes 2 ft. 9 ins. thick.

Lugton.—Mr. Richey finds that the Lower Limestone Group includes three limestones separated by shales. The succession is somewhat as follows:—

		Ft.	In.
Upper Limestone.	Thin black encrinital posts, with encrinital shales and lamellibranch shales at the base ... about	18	0
	Shale ... ... about	15	0
Middle Limestone.	Ostracod band ... ... from 8 in. to	1	0
	White band ... ... from 2 ft. to	3	0
	Dark band with large corals ... ... from 1 ft. to	10	0
	Lithostrotion junceum band ... ... from 3 in. to	1	0
	Dark band with few fossils	5	0
	Lithostrotion junceum band	1	0
	White bands split up by shales ... ... about	8	0
	Calcareous shale	7	0
	Pyritous shale ... ... about	0	6
	Coal	1	6
	Fireclay ... ... about	12	0
Lower Limestone.	Green band ... ... about	5	0
	Calcareous shales and hard calcareous bands and nodules	12	0
	Ashy sandstone and fine volcanic conglomerate or tuff.		

In a cliff section on the Lugton Water about a quarter of a mile below Lugton the lower limestone is seen with an inconstant band of *Naiadites crassa* (Fleming)[1] immediately above the ashy sandstones. The green limestone is a compact brittle rock containing giganteid Producti and dendroid Lonsdaleias. The middle limestone is well exposed in quarries and railway cuttings.

The ostracod limestone is fine-grained and dark in colour when fresh, but weathers with a red, nodular crust; minute concretions of sphaerosiderite occur throughout, and besides ostracods it contains fish remains—teeth, scales and bones—and a few corals, shells and foraminifera. In places it is brecciated on a small scale.

Coal Measures.

Mossend and Motherwell.—Mr. Clough has detected several exposures of Skipsey's Marine Band which do not appear to have been hitherto noticed. As this band seems fairly constant throughout the Scottish Coalfields, and may in future prove of

[1] *See* R. Craig. *Trans. Geol. Soc., Glasgow*, vol. iii, 1869, p. 295; and vol. v, 1874, pp. 42 and 49.

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considerable help as an index bed, it is desirable to describe the fresh information in some detail. Two of the new exposures are on the South Calder, one a little above and the other a little below the bridge nearly half a mile W.N.W. of Jerviston House. A third crop is seen in the north bank of the Clyde about 70 yds. below the Camp Viaduct. Two other exposures are still very well seen in the railway cutting about half a mile south of Motherwell Station, where Mr. Macconochie found the bed many years ago.[1] In all these localities the bed has much the same character, being a dark grey limestone, rather shaly in places, and only about a foot thick, but so hard in the main that it breaks up into big slabs, and in natural exposures projects considerably beyond the other strata. The dark grey colour is very like that of many bands of shale or fakes, and this is probably the reason the bed has not been recorded in the journals of many shafts and bores which must have gone through it. A drop of dilute hydrochloric acid gives rise to an almost explosive effervescence, and marine fossils are generally soon found. A list of the fossils collected this year by Mr. Tait from the railway cutting is given on p. 63.

In the cutting and near the Camp Viaduct, and again in the upper of the two exposures on the South Calder, a thin coal seam lies immediately under the marine band.

It is to be noted that no red beds are seen in this section, nor indeed, judging from the journals of various neighbouring bores, do any red beds appear to occur in this locality on any horizon between Skipsey's Marine Band and the Ell Coal. This is very different from the state of matters a few miles further north.[2]

The Palacecraig section at which Skipsey's Marine Band was found a few years ago[3] lies about three and a half miles north of the South Calder exposures, and it is interesting to notice that the beds between the Ell Coal and Skipsey's Band are much thinner near these exposures than at Palacecraig. At Palacecraig the thickness of the beds between the Upper Coal and Skipsey's Band was estimated as 53 fms. and that between the (base of the) Ell Coal and Skipsey's Band is probably about 73 fms. On the other hand, if we calculate from levelled positions indicated in the Splint Seam workings of Braidhurst Colliery (Summerlee Iron Co., Ltd.) which adjoin the South Calder exposures of Skipsey's Band, it is found that the strata between the (base of the) Ell Coal and this band have now diminished to about 56 fms. This considerable diminution makes it appear quite possible that the six-inch limestone recorded in the shaft section of Bothwell Castle No. 3 Pit, which lies rather more than four miles west of Motherwell, may be Skipsey's Band after all.[4]

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[1] A list of fossils then obtained from this locality is given in the 'Explanation of sheet 23' (*Mem. Geol. Surv.*), 1874, pp. 54, 92.

[2] 'Summary of Progress for 1908' (*Mem. Geol. Surv.*), 1909, pp. 63–64.

[3] J. Smith and C. T. Clough. 'Summary of Progress' for 1907 (*Mem. Geol. Surv.*), 1908, p. 127. On p. 135 the scale of the vertical section has by mistake been put as 1 in. = 200 feet, instead of 1 in. = 100 ft. The position of the Upper Coal in the Drumpark section has also been drawn too low.

[4] 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), 1911, p. 77.

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An additional diminution appears to occur in a southerly direction between the South Calder and the Camp Viaduct, but this probably amounts to only about 3 fms.

It may be mentioned that in the Barony Pit sinking, now being made by Messrs. William Baird & Co., Ltd., near Auchinleck, Ayrshire, Skipsey's Marine Band with its usual marine fossils and lithological character has lately been passed through, and that from the data provided by this sinking and an adjacent bore the distance between the (base of the) top thick coal, called the Ell Coal, and this band is calculated to be about 35 fms.[1] The Barony sinking lies about 25 miles S.S.W. of the Camp Viaduct.

Near the junction of two burns about 200 yards north-east of Shirrell, several thin coals and musselband ironstones are exposed. The measures are much confused with faults, but it is believed that they all lie between the Upper Coal and Skipsey's Marine Band. The ironstones have been searched by Mr. Tait, and he has found abundant remains of *Lingula squamiformis* in the top one.

Cleland.—It has long been known that wants often occur vertically, or almost vertically above one another in several successive coal seams. An example of this, occurring at Spindleside Pit, near Cleland, was visited by Mr. Anderson. In this case the want is linear, running from west to east. It affects the Kiltongue, the Upper Drumgray, and the Lower Drumgray,

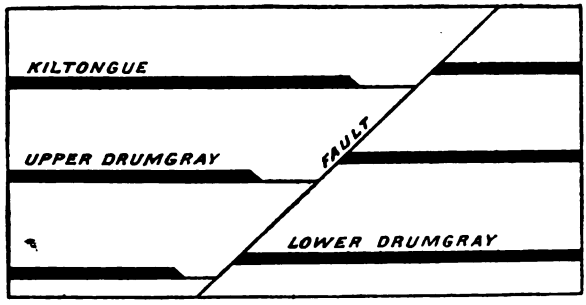

FIG. 1.—"Wants" in successive Coal Seams adjacent to a Fault, Spindleside Pit, Lanarkshire.

occupying a position progressively further north in the two lower seams. Its southern margin is formed in all three cases by an east-and-west fault with downthrow to the north of not more than a foot or two, with which the wants are in evident connection.

INTRUSIVE IGNEOUS ROCKS.

Mossend.—A whin dyke striking north-west is exposed in various places in the underground workings of Hattonrig Colliery

[1] It is now clear that the limestone indicated in the bore-journal 51 fm. above the top of the Ell Coal, and referred to by Messrs. Smith and Clough in a footnote on p. 133 of the Summary of Progress for 1907, does not represent Skipsey's Band, but must be some other bed nearly 100 ft. higher. This higher bed has not been recognised in the material brought out from the sinking.

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(Summerlee Iron Co., Ltd.). In the hope of getting the rock in a sound condition Mr. Clough made an examination of the different exposures, with the kind assistance of the Company's officials, and found that where the dyke cuts the Lower Drumgray it is less decomposed than usual. Mr. Bailey has examined the thin slice (15495) of the specimen obtained from this locality, and reports that under the microscope the rock proves to be particularly rich in small idiomorphic crystals of purplish augite, which is accompanied by felspar, olivine (represented as pseudomorphs), magnetite and fresh brown hornblende. The felspar, so far as it is determinable, is oligoclase, in small columnar crystals enclosing the other constituents. There appears to have been fibrous variolitic felspar in the groundmass. The structure is panidiomorphic. Ocelli containing similar felspars, with abundant hornblende, calcite and analcite are frequent: the analcite has crystallised later than the calcite. The rock is considerably decomposed but may be classed as a camptonite, and agrees with many camptonitic dykes described by Dr. Flett[1] from the West Highlands, where it is supposed that they may be of Tertiary Age.

Apart from its peculiar petrological character this Hattonrig dyke is of interest because it sends off a number of thin sills laterally, especially where it comes into contact with coal seams, but the sills observed (in the measures just above the Pyotshaw Seam, and in the Blackband and Virtuewell Coals) do not extend more than 10 or 12 yds. from the dyke. It may be added that Mr. W. Jarvie, of the Bothwell Castle Collieries (Messrs. William Baird & Co., Ltd.), states that the W.N.W. whin dyke that passes a little south of Craighead House gives off sills (floats) into every coal seam worked near it, and that a sill in the Ell Coal extends as much as 44 yds. from the dyke.

Saltcoats and Ardrossan.—The Castle Rock of Ardrossan shows fine curved columnar structure towards steeply inclined margins. This fact, with the massive nature of the rock, and the comparative absence of vesicles, makes it tolerably certain that it is an intrusion.

The intrusive sill shown below the Little or Wee Coal in the old edition of the one-inch map is exposed in the cutting along the Caledonian Railway a little north-east of Saltcoats. In this section Mr. Anderson finds that it contains a thickness of at least 12 feet of picrite. The same sill is exposed in the Caponcraig Gaw Quarry, west of Stevenston, where it is in three parts, but does not contain any picrite. The strata have here been remarkably twisted, in a way which affords clear evidence against the replacement theory of intrusion. The three divisions are cut by the north-western dyke—the Caponcraig Gaw—for which the quarry was mainly wrought.

Pleistocene and Recent.

Mossend and Motherwell.—Thick deposits of sand and gravel are seen below boulder clay in various surface exposures and

[1] 'The Geology of the Country near Oban and Dalmally' (*Mem. Geol. Surv.*), 1908, p. 125.

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colliery workings. Some of these were noticed by Prof. J. Geikie during the original survey, and were supposed by him to occupy preglacial and interglacial stream channels.[1] Mr. Clough has examined some of these beds, and believes that at whatever period the channels may have been initiated, the sands and gravels now found in them must have accumulated for the most part after the commencement of the Glacial Period. Ice action, in some form or other, had already conveyed into the district boulders of various rocks which are only found *in situ* far outside the present drainage area. A good section of the beds in one of these old channels is exposed in the sand pit at Nether Johnstone, rather more than a mile east of Motherwell. The section varies in different parts of the pit, but at the north-east corner it is somewhat as follows:—

Boulder clay, from 2 ft. to 3 ft.			
Gravel	...	...	30 ft.
Sand	...	...	15 ft.

The gravel contains abundant boulders of Highland rocks, including some of garnetiferous mica schist, which have probably come from a considerable distance north-west of the Highland Border. These are mixed with others, such as radiolarian chert and pink felsite, like the Tinto Hill rock, which have probably come from a southern source. A bore hole has been put down from the bottom of the pit, and passed through 100 ft. of sand without reaching the bottom, so that none of the beds in the pit can be near the bottom of the old channel. But in Coursington Colliery, rather more than a mile further west, the same channel appears to be again met with, and gravels which are believed to be very near the bottom of it cut through the Main Coal at a depth of about 110 ft. below the surface. These gravels have been examined, on one occasion with the kind assistance of Mr. R. W. Dron, and it has been ascertained that they contain pebbles not only of radiolarian chert, and pink felsite like that of Tinto Hill, but also a fair number of pieces of sheared grit, like rocks common along the Highland Border.

Among the boulders separated from the boulder clay used for making bricks in the brickworks at Carfin that belong to the United Collieries Co., Ltd., Mr. Clough detected a calcareous "coal ball" of the type that occurs in the Coal Measures of Lancashire. Such coal balls do not appear to have been yet found *in situ* in Lanarkshire, and unfortunately it has not been possible to trace the Carfin boulder to its source.

Economics.

Cleland and Newarthill.—Mr. Anderson reports that in this district the Ell Coal, the Main Coal and the Splint have all been wrought a first time (on the stoop and room principle) over their entire area. In some cases the stoops have been removed in bulk, while in others a second and sometimes a third system of rooms has been driven through them. Where any of these three coals

[1] '**Explanation of Sheet 31**' (*Mem. Geol. Surv.*), 1879, pp. 50–51.

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remains it is in the form of narrow pillars, and in the case of the Ell Coal any attempt to work these is fraught with more or less danger of spontaneous combustion. The Humph Coal is being wrought at one colliery in this district, and is not much disturbed in spite of the fact that the Splint Coal has been wrought out three fathoms below it. The Virtuewell Coal is also mostly out, and what coal is left in the district is mainly in the Kiltongue, Upper, Mid, and Lower Drumgray Seams. Of these the Kiltongue is usually thin, and although the Upper Drumgray is in places a good seam it is elsewhere hardly thick enough to form a workable subject. The Mid Drumgray is only present in any thickness near Newmains. It is the Lower Drumgray which is most constant, and probably will be the greatest factor in the future development of this district.

5.—Oil Shales.

During the past year Mr. R. G. Carruthers was engaged in a revision of the Scottish Shale-fields, in connection with the forthcoming new edition of the Oil-Shale Memoir.

The information obtained in former surveys was checked as far as possible and much new material obtained, the various companies concerned having given access to plans, bore journals, &c., in a very generous manner.

The main points observed during the revision may be tabulated as follows:—

(1.) Modifications of the general sequence of strata, with a separation of the Barracks and Burdiehouse Limestones, the former being of local occurrence and lying at the base of the Dunnet group of shales, with the Burdiehouse Limestone (at Deans) 120 fathoms below. The suggestion is made that the Dalmahoy Shale lies below the Pumpherston position.

(2.) The discovery of two horizons of marine fossils (*Goniatites*, *Orthoceras*, &c.), one lying towards the top of the Oil-Shale Group, under the Mungle Shale, the other much lower down, beneath the Pumpherston Shales. These shell-beds have been traced throughout the shale-fields, and have, amongst other results, led to the identification of the valuable Pumpherston Shales in the northern fields.

(3.) A new reading of the Queensferry coast section, east of the Forth Bridge, the so-called Dunnet Shale and Limestone being now identified with the Burdiehouse position, and the bed formerly regarded as the Burdiehouse Limestone being now correlated with a limy cement at the base of the Pumpherston Shales.

(4.) Four new outcrops of the Burdiehouse Limestone have been noted, these being of importance on account of the possibility of finding the Pumpherston Shales not far beneath: these seams are now more valuable than others owing to their high yield of ammonium sulphate.

(5.) The recognition of some new lithological horizons of use in boring for certain shales: the most widespread of these is the

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Barracks Ash, a volcanic bed which has been followed throughout the main shale region of West Lothian.

(6.) A distinction has been drawn between the behaviour of the teschenite and quartz-dolerite sills: the former, of which at least five have a wide lateral extent, transgress but slightly from their respective horizons, and have a certain stratigraphical value, but the quartz-dolerites often change their position with great rapidity.

(7.) As before, the Cobbinshaw Limestone and Coal is taken as the base-line of the overlying Carboniferous Limestone Series on the west side of the main shale region, but, in accordance with recent work along the south side of the Lanarkshire Coal-field, this bed is now considered to be somewhat below the Hurlet Limestone of the West of Scotland, hitherto taken as the base of the Series.

The base-line of the Oil-Shale Group has been drawn at the top of the Corston Hill and Arthur's Seat lavas, as there is evidence that oil shale conditions then set in all over Mid and West Lothian.

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III.—PETROGRAPHICAL WORK.

(1) England and Wales.

Petrographical work during 1911 was carried on chiefly in connection with the districts of South Wales and Devon and Cornwall, the results of which have, in several cases, already been embodied in Memoirs descriptive of those districts.

Prof. O. T. Jones has made a special study of the supposed pre-Cambrian rocks of southern Pembrokeshire and has prepared an account of these rocks for the Memoir on the geology of the Haverfordwest district which is now in the press. In this pre-Cambrian complex Prof. Jones recognises two distinct series of igneous rocks, the one volcanic the other plutonic in character, to which he has applied the names Benton Series and Johnston Series respectively.

The Benton Series consists of acid, soda-rich, volcanic rocks which may be grouped under the names felsite, spherulitic rhyolite, and breccia.

The Johnston Series comprises quartz-diorites, quartz-albite rocks, and quartz-dolerites. The quartz-albite rocks cut through the quartz-diorite, and the quartz-dolerites represent a still later intrusive phase.

Dr. Flett and Mr. Dewey have prepared a report on the petrography of the middle portion of the Dartmoor Granite and have made interesting observations on the progressive metamorphism of the Devonian and Carboniferous lavas of central Devon. They have also described a variety of granite (hornblende-aplite) which contains primary hornblende, and have given an account of the contact-altered rocks rich in fresh cordierite, scapolite, and andalusite.

Dr. Flett and Dr. Dewey contributed a petrographical chapter to the Memoir on the Tavistock district and dealt with the albite-spilites, albite-diabases, minverites, and hornblende-picrites. A mass of the last-named rock furnishes the well-known Polyphant stone which is allied to the picrite of Criffle Mill.

Dr. Flett, having completed his investigation of the rocks of the Lizard Peninsula (Sheet 359), has written an account of their petrography and field-relations for the Memoir which is now in the press.

Mr. Barrow reports that the Culm-Measures in the neighbourhood of the Dart Valley, on the east side of the Dartmoor Granite, are unaffected by shearing stresses and show the effects of purely thermal metamorphism. Cordierite is abundantly developed in these rocks and is often perfectly fresh. Mr. Barrow also records cordierite-bearing rocks from the eastern portion of the aureole of metamorphism around the Bodmin Moor Granite. In the calcareous rocks which come within the influence of this granite-mass, idocrase, garnet, and pyroxene are abundantly developed, but Mr. Barrow states that the idiomorphic and markedly anomalous garnets as well as minerals such as axinite are distinctly rare.

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From the same district Mr. Barrow records the comparatively rare mineral rhodonite, which occurs as microscopic crystals in certain metamorphosed calcareous shales situated near the outer margin of the metamorphic aureole.

(2) Scotland.

Dr. Flett has furnished a petrographical account of the Lewisian Inliers of Sheet 82, being the district of Central Ross-shire.

These inliers comprise hornblende-gneisses, biotite-gneisses, amphibolites, pyroxene-gneisses, eclogites and a set of ultra-basic dyke-rocks (peridotites, etc.). They also include a series of rocks of recognisably sedimentary origin such as metamorphosed limestones and graphitic mica-schists.

Dr. Flett has also contributed a petrographical description of the later igneous intrusions of this district. The rocks described fall into two groups, the one older and the other younger than the foliation of the gneisses. Those earlier than the foliation are all basic in composition and have been completely metamorphosed; the younger group comprises lamprophyres, vogesites, minettes, olivine-basalts, monchiquites and camptonites.

In the spring of 1911 Dr. Flett and Mr. Bailey investigated the contact-alteration of the sedimentary schists in the neighbourhood of the plutonic masses of Ben Nevis and Glencoe.

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IV.—CHEMICAL WORK.

The following analyses refer to two specimens mentioned in the Memoir on the 'Geology of Ben Wyvis, Carn Chuinneag, Inchbar and the surrounding Country.' (Explanation of Sheet 93, Scotland), p. 70 (footnote):—

S 14934. (Lab. No. 362.)
Marginal part of Epidiorite sill in Moine Gneisses, right bank of river Carron, $\frac{1}{8}$ mile N.N.E. of Glencalvie Lodge, Ross. One-inch map 93, Scotland.

S 14935. (Lab. No. 363.)
Central part of sill of Hornblende Schist in Moine Gneiss; same locality as S 14934.

	14934.	14935.
SiO_2...	44·10	47·03
TiO_2...	3·07	3·09
Al_2O_3	13·63	15·11
Fe_2O_3	·76	·91
FeO...	11·35	11·35
MnO	·35	·42
(Co Ni) O	·04	not found
BaO...	not found	not found
CaO...	7·96	8·55
MgO	5·58	6·47
K_2O...	4·34	1·82
Na_2O	1·26	2·30
Li_2O	not found	not found
H_2O at 105° C.	·17	·22
H_2O above 105° C. ...	2·05	1·77
P_2O_5	·22	·36
FeS_2	·09	·16
CO_2...	5·18	·65
Total	100·15	100·21

Analyst,
E. G. Radley.

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V.—PALÆONTOLOGICAL WORK.

(1) England and Wales.

The specialists who have been asked to report on specimens from the Survey and Museum collections during the year are as follows:—Mr. S. S. Buckman, Miss G. L. Elles, Dr. Wheelton Hind, Dr. G. J. Hinde, Dr. R. Kidston, Mr. P. Lake, Dr. C. A. Matley and Dr. A. Smith Woodward. The revision of the collection of Inferior Oolite ammonites by Mr. Buckman is well advanced.

Dr. Ivor Thomas has taken a substantial share in the work of examining specimens collected during the course of the current Survey. He has also continued his systematic researches on the Carboniferous Productids, and has brought together some of his results with a view to their early publication as a Memoir of the Survey. Since this will form a complete unit in itself, it has been thought advisable not to delay its issue until the whole of the projected work on these fossils can be completed. Dr. Thomas has found it necessary to introduce several new generic divisions to include species formerly referred to *Productus*. The general scheme of classification will be discussed in the part of the monograph now in advanced preparation, which will also contain an account of previous work on these fossils, as well as observations on terminology and on the morphology and structure of the shells. This section of the work will therefore serve as an introduction to the whole subject.

Among the memoirs passed through the press during the year, that "On the Mesozoic Rocks in some of the Coal Explorations in Kent," by Messrs. G. W. Lamplugh and F. L. Kitchin, contains many observations on the palæontology of the strata between the Gault and the Trias, present in the four sections described in the memoir. It is hoped that this account will prove a useful basis for future work in correlating the hidden Mesozoic rocks penetrated by other borings and sinkings in Kent.

Mr. J. Pringle visited Fretherne, in Gloucestershire, in order to collect specimens of *Gryphaea* from the well-known section of Lower Lias at Hock Cliff. He obtained a fine series of shells, which should prove of value in helping to elucidate the nature and origin of those ostrean forms which have hitherto been roughly classed together as *Gryphaea*. Many of these specimens show well the transitional stages between the ancestral simple oysters of flattened form, with prolonged attached stage, and the extreme morphological type characterised by a greatly reduced attached stage and a strongly arcuate left valve. Dr. Kitchin has found prodissoconch-stages in the right valves of a few well-preserved individuals. He believes that the specimens comprised in this collection contribute some valuable evidence in support of the view that the features usually considered to characterise *Gryphaea* are not those of a long-lived genus but of a similar evolutionary stage which has appeared repeatedly and independently in various ostrean stocks. It is evident that in the Lower Lias alone there were two or three separate derivations for such forms. The evolution of analogous gryphæate stages was repeated in other stocks in various Jurassic and Cretaceous horizons. These stages seem

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never to have had a place in any main line of evolution, but to have arisen rapidly and to have characterised short-lived offshoots from ostrean radicals. Their study not only has great theoretical interest, by reason of the light it may help to throw on questions in which phylogenetic principles are involved; it must also lead to a better characterisation of the faunal assemblages in which gryphæate oysters are found, and will have a corresponding practical value in zonal work.

Mr. Pringle visited the neighbourhood of St. David's and obtained a series of fossils from the Cambrian rocks at some of Hicks's type-localities. He was also given the opportunity to cross to Ramsey Island for the purpose of examining and collecting from the so-called 'Lower Tremadoc' rocks at the north end of the island. It was found that the doubts which had arisen concerning the age of those beds were well justified, and that the strata in question belong really to the Arenig and not to the Tremadoc Series, as supposed by Salter and Hicks. Among the fossils obtained were *Calymene tristani* Brongn. [=*Neseuretus ramseyensis* Hicks] and *Oggygia selwyni* (Salter). Mr. Pringle communicated his conclusions in a short paper to the 'Geological Magazine.'

Mr. Allen has arranged a case in the Museum to illustrate some of the fossils characteristic of the zones of the British Jurassic rocks from the Lias to the Great Oolite, inclusive. Two fine examples of *Lepidodendron lycopodioides* Sternberg, from the Coal Measures of Lancashire, have been exhibited in temporary cases.

The British fossils from the collection of the Geological Society, presented to the Geological Survey by the Society, have been transferred from Burlington House, and a large number of them have been placed on exhibition in their respective stratigraphical positions in the Museum. This munificent gift forms a very important addition to the Museum. It comprises many types and figured specimens, including some 300 figured in Murchison's classic 'Silurian System,' and contains important suites of fossils illustrating papers by eminent authors, which have appeared from time to time in the publications of the Geological Society. These are now made more widely available for the illustration of British stratigraphical geology. Mr. Allen has arranged special cases for the display of a set of typical specimens from the Murchison collection, for a series of fish-remains from the Jones collection, and for a suite of fossils from other sources, formerly in the keeping of the Geological Society.

The following specimens in the Museum have been figured and described during the year:—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1910.

(Published 1911.)

Cretaceous Lamellibranchia of England.

By MR. HENRY WOODS, M.A.

Inoceramus neocomiensis *d'Orb.*, **pl. xlv, fig. 1.**
,, concentricus *Park.*, **pl. xlvi, fig. 8.**
,, ,, var. subsulcatus *Wiltsh.*, **pl. xlvii, figs. 5, 14.**
,, crippsi *Mant.*, **pl. xlviii, fig. 2.**

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British Graptolites.

By Miss G. L. Elles, Sc.D., and Miss E. M. R. Wood, D.Sc.

Monograptus acinaces *Törnquist*, pl. xxxvi, figs. 2a, b, d, and Text-figures 237a, b, d, p. 364.
" concinnus *Lapw.*, pl. xxxvi, figs. 5d, f, and Text-fig. 240d, p. 369.
" leptotheca *Lapw.*, pl. xxxvii, fig. 2c.
" regularis *Törnquist*, pl. xxxvii, figs. 3b, d, and Text-fig. 243a, p. 373.
" nudus (*Lapw.*), pl. xxxvii, fig. 6b, and Text-figs. 246a, c, p. 376.
" revolutus *Kurck*, pl. xxxviii, fig. 1d.
" " *var.* praecursor *E. & W.*, pl. xxxviii, fig. 3a, and Text-figs. 255b, c, p. 386.
" atavus *Jones*, pl. xxxix, figs. 1a–c, and Text-figs, 270c–e, p. 404.
" sandersoni *Lapw.*, pl. xxxix, fig. 10d, and Text-fig. 271c, p. 405.
" incommodus *Törnquist*, pl. xl, fig. 1d.
" tenuis (*Portl.*), pl. xl, figs. 2a–d, and Text-figs. 273a–d, p. 407.
" argutus *Lapw.*, pl. xl, figs. 3b, d, e, and Text-figs. 274a, e, f, p. 408.
" griestoniensis (*Nicol*), pl. xli, figs. 5a, b.
" limatulus *Törnquist*, Text-fig. 259c, p. 390.

Carboniferous Arachnida.

By Mr. R. I. Pocock, F.L.S.

Graeophonus anglicus *Pocock*, pl. i, fig. 4d.
Anthracomartus hindi *Pocock*, pl. iii, fig. 3.
Kreischeria verrucosa *Pocock*, pl. iii, fig. 5, and Text-fig. 40, p. 78.
Aphantomartus areolatus *Pocock*, pl. iii, fig. 6, and Text-fig. 41, p. 81.

In the Quarterly Journal of the Geological Society, Vol. LXVII.

By Mr. H. Bolton, F.R.S.E., F.G.S.

Archimylacris spp. indet., pl. vii, fig. 2, and pl. x, fig. 3.
" (Schizoblatta) obovata *Bolt.*, pl. vii, figs. 4, 5.
" (Etoblattina) hastata *Bolt.*, pl. ix, figs. 1, 2.
Hemimylacris convexa *Bolt.*, pl. vii, fig. 3.
" obtusa *Bolt.*, pl. x, fig. 4.
Gerablattina (Aphthoroblattina) sulcata *Bolt.*, pl. viii, figs. 1, 2.
Orthomylacris lanceolata *Bolt.*, pl. x, fig. 1.
Lamproptilia tenuitegminata *Bolt.*, pl. x, fig. 6.

In the Geological Magazine, Dec. 5, Vol. VIII.

By Mr. A. H. Noble, B.A.

Desmoceras marlowense *Noble*, pp. 398-400. Text-figs. 1, 2.

In the Proc. of the Cotteswold Naturalists' Field Club, Vol. XVII., Part 2.

By Mr. E. Talbot Paris, F.C.S.

Gervillia aurita *Lycett*, pl. xxix, f. 6.
" compressa *Whidborne*, pl. xxix, f. 5.
" crassa *J. Buckman*, pl. xxviii, figs. 1a–d.
" fornicata *Lycett*, pl. xxviii, f. 3.
" islipensis *Lycett*, pl. xxix, f. 4.
" laevis *J. Buckman*, pl. xxviii, figs. 2a, b.
" ornata *Lycett*, p. 248.
" praelonga *Lycett*, p. 249.

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In "Yorkshire Type Ammonites," Part 5.

By S. S. Buckman and J. W. Tutcher.

Xipheroceras scoresbyi (*Simpson*), pl. xxxix c.
Pseudolioceras compactile (*Simpson*), pl. xli a.

(2) Scotland.

In connection with the course of geological mapping, fossils have been collected from the Carboniferous areas of Central Scotland and the Mesozoic rocks of Mull. Many of the specimens have been examined by Dr. G. W. Lee, while the fishes, the plants, the Mesozoic cephalopods and the Carboniferous lamellibranchs have been submitted to Dr. Traquair, Dr. Kidston, Mr. S. S. Buckman and Dr. Wheelton Hind, respectively.

Messrs. Tait and F. Macconochie collected from the Mesozoic rocks of the Lochdonhead district, Mull, and obtained materials which have enabled Mr. Buckman to add considerably to our knowledge of the Mull Mesozoic sequence, as sketched in the 'Summary of Progress' for 1909, pp. 29-30 and 57.

Middle Lias.—On the east side of Port nam Marbh the white sandstone overlying the Lower Lias beds characterised by *Pecten equivalvis* J. Sow., yielded a specimen of *Amaltheus depressus* (Simpson). This white sandstone is, therefore, without a doubt of Middle Lias age, and belongs to the Margaritatus or to the Algovianum Zone.

Upper Lias.—In additional materials from the Upper Lias shale of Port Donain, Mr. Buckman determined a species of *Harpoceras* typical of the Bifrons Zone, and a *Dactylioceras* doubtfully referred to *D. semicelatum* of the Tenuicostatum Zone.

Lower Oolites.—As the index-ammonites of the Mull Lower Oolites are of somewhat sporadic occurrence, and are, moreover, not easily extracted from their matrix, it will be necessary to make further search before the series can be finally subdivided into the finer zones of Mr. Buckman's classification.

From the evidence obtained in the lower half of the limestone series overlying the Upper Lias, Mr. Buckman recognises the presence in the coast-section of the Blagdeni, Discitae, Concava and Bradfordensis Zones (with suggestions of the Sauzei and Dumortieriæ Zones). Ammonites characteristic of the Scissi Zone occur in the Ardnadrochet Glen. The above is not a complete sequence, but it is probable that the unrecorded zones are not missing, but obscured by paucity of materials.

Callovian.—From the right bank of the stream flowing half a mile south-east of Duart House, Messrs. Tait and Macconochie obtained a suite of ammonites which, according to Mr. Buckman's report, appear to indicate the Anceps Zone of the Callovian. This is a most unexpected discovery, since no evidence of the Anceps Zone seems to have been met with in Great Britain before.

The specimens being poorly preserved, the following determinations are to be regarded as provisional:—

Cosmoceras elizabethae (*Pratt*) [*Quenstedt*]
,, *aff.* fraasi (*Oppel*)
,, *cf.* kiliani *Parona and Bonarelli*
Reineckeia anceps? (*Reinecke*)
,, *aff.* fraasi (*Oppel*)
,, *cf.* kiliani *Parona and Bonarelli*

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Speaking of these, Mr. Buckman says:—"It may be noted that the usual suite of species of *Cosmoceras* characteristic of the British Ornatum Zone is not represented. Of the species of *Reineckeia* all differ in small particulars from the species whose names have been assigned to them; but the condition of the materials does not allow much to be said on this point."

Cenomanian.—On p. 30 of the 'Summary of Progress' for 1909, mention is made of the occurrence near Port na Tairbeirt of a sandstone assigned to the Upper Greensand on account of its lithological resemblance to beds which at Carsaig are referred to that formation. The ammonite *Schloenbachia intermedia* (Mantell) having been obtained from this sandstone, its Cenomanian age is now satisfactorily established.

Carboniferous Rocks.—Fuller information has been acquired concerning the Upper Carboniferous marine fauna of Central Scotland. Skipsey's Marine Band, described by Messrs. Smith and Clough in the 'Summary of Progress' for 1907, p. 127, has now been got in the Barong Pit sinking, Ayrshire, where it occurs as a limestone about 35 fms. above the base of the top thick coal, called Ell Coal, and about 1,173 feet below a plant bed with Upper Coal Measure plants. The following is the list of the fossils obtained from this limestone by Mr. Tait:—

Crinoid ossicles
Fenestellid
Chonetes laguessiana *de Kon.*
Lingula squamiformis *Phill.*
,, mytiloides *J. Sow.*
Productus sp. nov. [*cf.* parvulus *Nikitin*]
Posidoniella sulcata *Hind*
Pterinopecten papyraceus (*J. de C. Sow.*)
Scaldia carbonaria *Hind*
?Macrochilina sp.
?Gasteropod [*cf.* Trepospira radians (*de Kon.*)]
Nautiloid shells
Goniatite

A marine shale occurring 9 fathoms lower down, has yielded *Lingula mytiloides* J. Sow., lamellibranchs and gasteropods, including a Bellerophontid.

The fauna of this limestone is very similar to that of the limestone seen in the railway-cutting half a mile south of Motherwell Station, and in the north bank of the Clyde, one mile south of Motherwell. At these localities Mr. Tait obtained the following fossils:—

Crinoid ossicles
Ambocoelia *aff.* urei (*Flem.*)
Lingula mytiloides *J. Sow.*
Orbiculoidea nitida (*Phill.*)
Productus anthrax *Hind*
,, sp. nov. [*cf.* parvulus *Nikitin*]
Spirifer sp.
Posidoniella sulcata *Hind*
Pterinopecten carbonarius *Hind*
,, papyraceus (*J. de C. Sow.*)
Syncyclonema carboniferum *Hind*
Murchisonid
Orthoceras sp.
?Pleuronautilus costatus *Hind*
?Glyphioceras micronotum (*Phill.*)

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The above lists indicate a fauna of the same facies as that described by Messrs. Stobbs and Hind[1] from the Coal Measures of the English Midlands. These authors have shown how persistently thin marine beds in the Coal Measures can extend over large areas in spite of their inconsiderable thickness. Here also the characters of the beds are of a pronounced marine type indicating considerable ingress of the sea, which gives additional weight to the view that the marine bands at these localities are on the same horizon.

The possibility of using marine bands as index-beds in correlating strata is not confined to the Coal Measures. During the course of his revision of the Oil-shale fields of the Lothians, Mr. Carruthers was enabled to recognise the presence of two marine horizons, which proved to be of the greatest service in tracing the sequence from one shale-field to another. The lower of these beds lies at the base of the Pumpherston Shale and yields *Orthoceras*, goniatites and pectiniform lamellibranchs, which, though usually indifferently preserved, are sufficient to differentiate the bed—the Oil-shale Group being essentially non-marine. The other marine horizon occurs immediately below the Mungle Shale, at the top of the series, and is characterised by a rich and varied fauna consisting of numerous species of gasteropods, lamellibranchs and cephalopods. Several of these, from the Fordel railway-cutting near Inverkeithing, have been recorded in the 'Summary of Progress' for the year 1905, pp. 143-146. The gasteropods, which had not been identified when that report was published, are represented by abundant specimens of a *Ptychomphalina* allied to *P. atomaria* (Phill.), of *Euphemus urei* (Flem.) and of a fine ribbed species of *Bucanopsis*. *Macrochilina rectilinea* (Phill.) and *Tropidocyclus duchasteli* (L'Eveillé) are also present.

That conditions suitable to the development of this fauna extended over a large area, is shown by the fact that a very similar assemblage was obtained by Mr. Carruthers eighteen miles further south, from the cores of a boring near Cobbinshaw, which yielded the following species:—

Productus longispinus? *J. Sow.*
Aviculopecten sp.
Edmondia sp.
*Posidonomya becheri *Bronn*
*Sanguinolites variabilis *M'Coy*
*Bucanopsis sp. nov.
*Ptychomphalina *aff.* atomaria (*Phill.*)
Orthoceras gesneri (*Martin*)
Stroboceras?
*Glyphioceras micronotum? (*Phill.*)
* ,, truncatum (*Phill.*)

The species common to the two localities are marked with an asterisk. It is remarkable to find such a close agreement considering that this list is based on the limited materials from a boring of small diameter; a favourable field exposure would probably yield a larger number of forms common to the two localities.

[1] 'The Marine Beds in the Coal Measures of North Staffordshire.' *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 495.

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It is hardly necessary to add that, in the foregoing remarks, these marine beds are not considered to be anything of the nature of life-zones; they are horizons recognised by their aggregate contents, which differ widely from those of the strata above and below.

Valuable additions have been made to our knowledge of the extension of the Middle Coal Measures in Ayrshire, as shown in Appendix V. kindly supplied by Dr. Kidston.

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VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Palæontological Department of the Museum has been enriched by an exceptionally fine series of British Fossils, the gift of the Geological Society of London. From the same source the Petrological Department has received an extensive series of British rocks.

A selection from this Fossil collection has been arranged in the Inner Hall to illustrate some of Murchison's types, which are of great historical interest. The bulk of the collection is stored and available for reference.

A short guide to the Gem Stones in the Mineral Collections has been prepared by Mr. W. F. P. McLintock, and is now in the press.

The Building Stone Collection continues to grow. The limestones in the series have been provided with introductory labels and with fuller descriptive labels; photomicrographs have been exhibited alongside the stones wherever the structures show features of importance.

A relief-model of the Saltburn district, made by Mr. J. Foster Stackhouse, has been coloured under the direction of Dr. Strahan.

The Collection of tested samples of Roadstones has been further enlarged during the year. Since August the Museum and Petrological work on these stones has been done in collaboration with the Road Board, with Mr. E. J. Lovegrove acting temporarily as intermediary.

List of Donations during the year 1911.

Aktiebolaget Nord Kompaniet, Helsingfors, Finland.—25 specimens of Finland Granite.

Anderson, Dr. C.—19 specimens of analysed rocks from Australia.

Army and Navy Auxiliary Co-Operative Supply, Ltd., The.—Two specimens of "Roman Stone."

Bailey, E. B., Esq., F.G.S.—93 specimens of Swedish Rocks.

Baker, Lady.—12 slabs of coloured clays "Dorset Marble."

Barrow, G., Esq., F.G.S.—Five slides and specimens (Glacial Beds, Scilly Isles).

Bath and Portland Stone Firms Co., Ltd.—Two samples of Portland Stone "Roach."

Best, A. T., Esq.—A specimen of Diabase.

Boulton, Prof. W. S.—One specimen of Monchiquite from Monmouthshire.

Boynton, T., Esq., F.S.A.—Specimen of Marcasite.

British Cork and Asphalt Co., Ltd.—Specimens of Cuban Asphalt and kindred productions.

British Stone and Marble Co., Ltd.—Six dressed blocks of "Reconstructed" stone.

Burbury, W. W., Esq.—Specimen of Spanish Oil Shale and specimen of Spanish Antimonite.

Castleman, C., Esq.—Specimens of Bismuth, Pegmatite and Galena, from Sweden.

Dartmoor Prison, H.M., The Governor of.—A cube of Dartmoor Granite.

Down Mill Brick Co., Ltd.—Two samples of bricks.

Edgeworth-David, Prof. T. W., C.M.G., F.R.S., D.Sc., &c.—Antarctic rocks and Algal Peat.

Flett, Dr. J. S., M.A., D.Sc., &c.—204 specimens of the trap-dykes, and corresponding rock-slides from the Orkney Isles. Four specimens of *Dipterus valenciennesi* Sedgw. and Murch.; three of *Coccosteus decipiens* Ag.; and one of *C. minor* Miller, from the Old Red Sandstone of Orkney.

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FREEMAN, MESSRS. JOHN, SONS AND CO., LTD.—Photographs of their Cornish Granite Quarries.

GEOLOGICAL SOCIETY OF LONDON, THE.—An exceptionally fine and extensive series of British rocks and fossils, being part of the Society's collection.

HALL, T. CLIFFORD, ESQ., F.G.S.—47 specimens of rocks from Lundy Island.

HAMLING, J. G., ESQ.—A series of fossils from the Devonian and Carboniferous of North Devon.

HESLOP, MISS M. H.—One slide and three specimens from Crookdene Dyke, Northumberland.

HIRSCHWALD, PROF. DR. J.—Illustrations of apparatus for the Testing of Building stones, as employed by him at Charlottenburg, Berlin.

HOPKINS, E., ESQ.—A series of "Reconstructed" Gems.

HORNER, MAURES, ESQ.—Two Ammonites and a *Terebratula* from the Lias of Vobster, and a series of Silurian fossils from the Mendip Hills.

HUTCHEON, H., ESQ.—Three specimens of Aberdeen Granite.

JOHNSTON, MISS.—Specimen of Norwegian Slate.

KO, S., ESQ.—Series of Japanese Minerals.

KUMAZAWA, J., ESQ.—A series of Aluminous Minerals from Japan.

MATLEY, DR. C. A.—55 specimens of Pillow Lavas, Lleyn Peninsula, N. Wales.

MACLAREN, DR. MALCOLM.—Five specimens from Hollinger and Porcupine Mines, Ontario.

MORGAN CRUCIBLE CO., LTD.—Sample of Plumbago and Monazite *in situ*.

MORROW-CAMPBELL, G. J., ESQ. — Obsidianite Bomb, from Western Australia.

MOYSEY, L., ESQ., B.A., M.B.—Two specimens of *Palaeoxyris helicteroides* (Morris), from the Middle Coal Measures of Derbyshire.

MURRAY, SIR J.—Specimen of Nepheline Syenite dredged from the North Atlantic.

MURRAY, J., ESQ.—Series of Coal Apples from Lanarkshire.

NICHOLLS, T., ESQ.—Two sample mouldings in Polyphant Stone.

PENTEWAN BRICK AND DEVELOPMENT CO., LTD.—A Building block.

PURDUE, R. F., ESQ.—A "Button" volcanic bomb from Tasmania.

ROGERS, INKERMAN, ESQ.—Three specimens of Devonshire Culm, also series of Clays, Sands and Gravels.

ROBERTS, ADLARD, & CO., MESSRS.—Samples of "Racephas" Stone and "R. A." Slate.

SANDALL, FRAU CECILIA.—Series of Swedish Minerals.

SCHMOLLE, EUGENE, ESQ.—Specimen of Erythrite from Lake Gowanda, Canada.

SEAFIELD, LADY (the late).—Four specimens of quartz (Cairngorm) mounted in stands.

SERGEANT, COL. SIR W. C. ELDON.—Specimen of Cassiterite from Cornwall.

ST. KEVERNE STONE CO., LTD.—Two samples of artificial Paving stones.

STEBBING, W. P. D., ESQ.—A specimen of Calcite from Reigate, Surrey.

STRAHAN, W. R., ESQ.—A specimen of *Onchotrochus* from the Chalk of Fulbourn.

TRENCH, COL.—Three specimens of barytes.

VECTIS STONE, SLATE AND BRICK CO., LTD.—Specimens of "Cephas" stone, slates and photographs of Quarries.

WETTERN, E., ESQ.—Six specimens of Irish Granites.

WHITEHEAD AND SONS, LTD., MESSRS.—Two specimens of Austrian building stones.

WILLS, L. J., ESQ., M.A., F.G.S.—A specimen of *Voltzia heterophylla?* Brongn. from the Lower Keuper of Hill Top, Bromsgrove.

WILSON, MRS.—A specimen of Turkish Oil Shale.

WORTH, B. H., ESQ.—Two specimens of Tourmaline Granite, from near Ivybridge, Devon.

WRIGHT, W., ESQ.—Specimen of Hertfordshire "Pudding Stone."

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VII.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year:—

(A.) ENGLAND AND WALES.

I.—MAPS.

(*a.*) *One-inch Maps* (*New Series*).

(Colour-printed, price 1*s.* 6*d.* each.)

Sheet 113, Ollerton (Drift).
Sheet 337, Tavistock (Drift).

A colour-printed Drift Edition of the following sheet has been issued in place of the hand-coloured edition:—
Sheet 42 [Old Series, 96 N.W.], Northallerton.

(*b.*) *Six-inch Reference Maps.*

Thirty MS. coloured copies of six-inch quarter sheets have been made from the field-copies, and deposited in the Office for public reference. These are as follows:—

Cornwall.—22 S.E.; 23 S.W.
Derbyshire.—11 N.W. (part), 11 N.E. (part), 11 S.W., 11 S.E. (part); 12 S.W.; 17 N.W., N.E., S.W., S.E.,; 18 S.W.; 19 S.W.; 24 N.W., S.W., S.E.; 25 S.W.; 29 N.W., N.E., S.E.; 30 N.W., S.W.; 34 N.E.; 35 N.W.
Devonshire.—105 N.W.
Essex.—74 N.W., S.W.
Lancashire.—26, 45.
Yorkshire.—112.

II.—MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1910, pp. 87. 6 illustrations. Price 1*s.*

The Mesozoic Rocks in some of the Kent Coal Explorations. By G. W. Lamplugh, F.R.S., and F.L. Kitchin, M.A., Ph.D., pp. 212. 5 illustrations, 5 plates. Price 3*s.* 6*d.*

The Water Supply of Sussex from Underground Sources (Supplement). By W. Whitaker, B.A., F.R.S., with contributions by H. R. Mill, D.Sc., LL.D., and H. F. Parsons, M.D., pp. 255. 2 illustrations, 1 map. Price 2*s.* 6*d.*

The Geology of the Country around Ollerton (Explanation of Sheet 113). By G. W. Lamplugh, F.R.S., J. B. Hill, R.N., W. Gibson, D.Sc., R. L. Sherlock, D.Sc., and B. Smith, M.A., pp. 93. 6 illustrations, 4 plates. Price 2*s.*

The Geology of the Country near Sidmouth and Lyme Regis (Explanation of Sheets 326 and 340). Second Edition. By H. B. Woodward, F.R.S., and W. A. E. Ussher, F.G.S., with contributions by A. J. Jukes-Browne, B.A., F.R.S., pp. 102. 39 illustrations, 1 plate. Price 1*s.* 6*d.*

The Geology of the Country around Tavistock and Launceston (Explanation of Sheet 337). By C. Reid, F.R.S., G. Barrow, F.G.S., R. L. Sherlock, D.Sc., D. A. MacAlister, A.R.S.M., and H. Dewey, F.G.S., pp. 146. 48 illustrations, 3 plates. Price 3*s.*

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(B.) SCOTLAND.

I.—MAPS.

(*a.*) *One-inch Maps.*

(Colour-printed.)

Sheet 28, Solid and Drift Geology, price 2*s.* 6*d.*
Sheet 35, Solid and Drift Geology, price 2*s.* 6*d.*
Glasgow District Map, Solid and Drift Geology, price 2*s.*
Sheet 65, Solid and Drift Geology, price 2*s.* 6*d.*

(*b.*) *Six-inch Maps of Mining Districts (New Series).*

Lanark.—8 N.E.; 11 N.W., S.W.

II.—MEMOIRS.

The Geology of the Glasgow District (Explanation of Glasgow District Map, including parts of Sheets 30, 31, 22 and 23). By C. T. Clough, M.A., F.G.S.; L. W. Hinxman, B.A., F.R.S.E.; the late J. S. Grant Wilson; C. B. Crampton, M.B., C.M.; W. B. Wright, B.A., F.G.S.; E. B. Bailey, B.A., F.G.S.; E. M. Anderson, M.A., B.Sc.,; R. G. Carruthers, F.G.S.; with contributions from G. W. Grabham, M.A.; J. S. Flett, M.A., D.Sc., F.R.S.E.; and a Chapter on the Palaeontology by G. W. Lee, D.Sc., F.R.S.E., pp. 270. 33 text figures, 1 colour-printed map. Price 4*s.* 6*d.*

The Geology of Knapdale, Jura and North Kintyre. (Explanation of Sheet 28, with parts of 27 and 29.) By B. N. Peach, LL.D., F.R.S.; the late J. S. Grant Wilson; J. B. Hill, R.N.; E. B. Bailey, B.A.; and G. W. Grabham, M.A.; with notes by C. T. Clough, M.A.; S. B. Wilkinson; W. B. Wright, B.A., and H. B. Maufe, B.A.; and Petrographical descriptions by J. S. Flett, M.A., D.Sc.; pp. 149. 7 plates, 8 text figures. Price 3*s.*

The Geology of Colonsay and Oronsay, with part of the Ross of Mull. (Explanation of Sheet 35, with part of 27.) By E. H. Cunningham Craig, B.A.; W. B. Wright, B.A.; with notes by C. T. Clough, M.A., and J. S. Flett, M.B., C.M., B.Sc.; pp. 109. 6 plates, 21 text figures. Price 2*s.* 3*d.*

Description of Arthur's Seat Volcano. By B. N. Peach, LL.D., F.R.S. (Reprint from the "Geology of the Neighbourhood of Edinburgh," 1910.) pp. 23. 4 text figures, 1 colour-printed map. Price 6*d.*

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APPENDIX I.

On a boring for Coal at Ebbsfleet, near Ramsgate.

By A. Strahan, Sc.D., F.R.S.

This boring was put down in 1911 by the Ebbsfleet Coal Syndicate, at a point 2¼ furlongs S. 5° E. of Ebbsfleet House. The following account is published by courteous permission of the Chairman, Mr. Mark Robinson, and Mr. G. C. Solley, Director.

The boring is situated on an alluvial flat of the River Stour, at a height of 10 feet above Ordnance Datum. I visited it on November 27th and found that the Coal Measures had been reached at 1,056 feet, immediately under Weald Clay with cyprids (*Cypridea valdensis*, *Metacypris fittoni*), and that at 1,159 feet a limestone had been entered, which I had little doubt was the Carboniferous Limestone, though I did not succeed in getting fossils. Subsequently a closer examination of the cores of the Lower Cretaceous Rocks was made by Mr. Lamplugh, and a search for fossils was carried out through the whole series by Mr. Pringle. The fossils mentioned below have been identified by Dr. Kitchin.

The following section is founded on their observations except as regards the estuarine sand and Thanet Beds, which were recorded by Mr. Hubbard, and of which no cores are in existence. The strata were horizontal or approximately so from top to bottom of the boring.

		Thickness.		Depth from surface.	
		Ft.	In.	Ft.	In.
Estuarine Alluvium and Thanet Sand.	Clay and sand with shell-beds ...	60	0	60	0
	Red clay	20	0	80	0
	Yellow clay	10	0	90	0
	Blue clay	20	0	110	0
Chalk.	Chalk with flints passing down into chalk without flints, and finally into chalk-marl	785	0	895	0
Gault.	Grey clay with glauconite and pale-grey fossiliferous clay. *Inoceramus* abundant at 990 feet. Dark-greenish glauconite clay at 1,003–1,005 feet	110	0	1,005	0
Folkestone Beds.	Hard calcareous sandstone, 10 inches, with marly sand to 1,009; then 3-inch concretionary sandstone, with sand below. Hard band of coarse grit and glauconite, 2 feet 2 inches thick, at 1,020½. Soft coarse glauconitic grit, with pebbles up to ¼ inch in diameter. Hard grit-band 1 foot thick, and glauconitic sand, to 1,031¾. At 1,034 feet a brilliant-green glauconitic band. Coarse rather muddy grit, with brown (? phosphatic) pebbles and lydites, at 1,035.	30	0	1,035	0

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		Thickness. Ft.	In.	Depth from surface. Ft.	In.
Sandgate Beds.	Dark muddy rather coarse glauconitic sand, with small brown 'pebbles,' possibly phosphatic. Shell-fragments and fragments of plants. At 1,041 a layer of coarse pebbly greensand with worn black nodules. This rests on an eroded surface of the clay below	6	0	1,041	0
Weald Clay.	Blue-grey clay with cyprids and dark-grey clay streaked and laminated with fine pale-grey silt. At the base a pebbly band is said to have occurred, but no specimen was forthcoming...	15	0	1,056	0
Coal Measures.	Grey micaceous shales with stigmarian rootlets, black shales with pyrites, and grey shale as above	43	6	1,099	6
	Coal	1	0	1,100	6
	Grey fireclay with stigmarian rootlets	4	6	1,105	0
	Grey sandy shale with *Sphenopteris* and shells	25	0	1,130	0
	Coal	0	9	1,130	9
	Dark micaceous shale with *Stigmaria*	21	3	1,152	0
	Black shale with many nodules of pyrites	7	0	1,159	0
Carboniferous Limestone.	Oolitic limestone with corals at 1,159; dolomitic limestone, oolitic in parts, with *Productus*	12	6	1,171	6
	Cream-coloured and dark-grey limestones, slickensided, with small productids	6	6	1,178	0
	Dark and light-grey limestones, in part oolitic, irregularly penetrated and mixed with shale and dark clay	100	0	1,278	0
	Pale-grey limestone with green shale, and cherty limestone becoming darker below, but containing oolitic bands. Crinoidal fragments, and at 1,349 fissures filled with dark clay	88	0	1,366	0
	Limestones (cores not seen)	23	0	1,389	0

The occurrence of *Productus corrugato-hemisphæricus* Vaughan, proves that the limestone belongs to the top of the Seminula or base of the Dibunophyllum zone of the Carboniferous Limestone. A noticeable feature in the limestone was its deeply-piped and honeycombed condition. Many of the cores consisted as much of shale as of limestone, and it was possible to see that the shale occupied pipes and chambers in the limestone which had the rounded outlines characteristic of solution-cavities. This piping of the limestone was most conspicuous down to a depth of about 1,278 feet, that is through a thickness of 119 feet of limestone, and down to that depth the clay or shale was such as might have been washed down from the Coal Measures. At about 1,300 feet depth a cavity had been filled with a dark-greenish clay, which may have been derived from the green shale noted in the section given above.

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Though it is unsafe to speculate on the condition the Carboniferous Limestone is likely to acquire when it lies buried under so great a thickness of later rocks, it may be pointed out that piping on this extensive scale is difficult to explain except on the supposition that water has at some time been free to circulate in the rock. Usually such circumstances have existed only where the limestone has been raised above water-level and exposed to sub-aerial denudation. The possibility of this having actually occurred before the Coal Measures were deposited has to be borne in mind, for at present the apparent absence of Millstone Grit requires explanation, nor is it known what part of the Coal Measures is resting upon the limestone. There may be a large overlap.

The section may be compared to that which was found in a borehole near the French Coast between Cap Gris Nez and Cap Blanc Nez in 1896-7.[1]

Sondage de Strouane.

	Thickness. Metres.	Depth from surface. Metres. Ft.
Cenomanian, Albian and Aptian ...	79·40	79·40 (259½)
Wealden	89·60	169·00 (552½)
Coal Measures:—Shales, &c., with three seams of coal, the lowest 9·30 m. above the base. At the bottom Sandstone 4·20 m. thick ...	124·20	293·20 (958½)
Carboniferous Limestone, proved to	6·30	299·50 (979¼)

That the northern margin of the Dover Coalfield has been struck in the Ebbsfleet boring is certain, but the approximate horizontality of the Carboniferous Rocks is an important point, for a slight reversal of dip would bring in the Coal Measures again further north. This point can be settled by boring only; the Secondary Rocks afford no clue whatever either as to the existence of the margin now proved, or as to the structure of the Palæozoic rocks further north.

The only boring which has as yet reached Palæozoic rocks to the south of the Dover Coalfield is situated at Brabourne. There, highly inclined strata, believed to be of Devonian or earlier age, were found to lie immediately below the Secondary formations.[2]

The glauconitic rocks in the Folkstone Beds are interesting. One of them [E 9197], which occurs at a depth of 1,034 feet, may be described as a glauconite-rock, inasmuch as the glauconite forms the matrix, binding together quartz-grains and other materials. It cannot be matched elsewhere in Kent, unless possibly in cores of some other borings not yet examined. The other [E 9191], from about the same depth, is comparable to glauconitic cherts and limestones which crop out in parts of Kent. The following descriptions are by Mr. H. H. Thomas:—

E. 9197.—A fine-grained rock of malachite-green colour, containing patches and films of calcareous mud of a pale-grey tint. The microscope shows the rock to be made up of about equal parts of quartz and glauconite.

[1] *Bulletins Geol. Survey of France*, vol. xv (1903, 4), No. 100, p. 118.

[2] 'Mesozoic Rocks in some of the Coal Explorations in Kent.' (*Mem. Geol. Surv.*), 1911, pp. 54–56.

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The quartz occurs in minute subangular grains which seldom touch one another. They are separated by bright-green glauconite, which appears to play the part of a cement. Small brownish rounded grains occur with the quartz, and seem to be a variety of glauconite in an oxidised condition.

The rock contains the remains of a few foraminifera (*Nodosaria*), but otherwise it is remarkably free from organic fragments of any description.

E. 9191.—Another rock from this boring, from about the same depth, is a good limestone, and contains patches and grains of bright-green glauconite.

The limestone is made up almost entirely of the remains of Bryozoa, fragments of the shells of Mollusca, chiefly lamellibranchs, and the remains of echinoderms.

In contrast to the rock described above, the glauconite occurs only infilling cavities left by the decay of organisms.

The cementing material is recrystallised calcite, which contains a considerable number of fairly large sub-angular quartz-grains. These quartz-grains show very little sign of wear.

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APPENDIX II.

On Diversions of the Bourne near Chertsey.

By C. N. Bromehead, B.A.

As one of the results of the recent mapping on the six-inch scale of a considerable area in the Thames Valley, it has become possible to differentiate the river gravels according to the terraces on which they lie. Though these terraces are well-known, a few fresh points of interest have come out, one of which, a case of stream diversion near Chertsey, due to planation by the Thames, is described below.

The most familiar names in use for these features are perhaps the 100-foot, 50-foot and low terraces. The numbers refer to the heights above Ordnance Datum at which the terraces are found in the London District, but these terraces rise as we trace them up-stream; for instance the 100-foot terrace occurs near Maidenhead at a height of about 150 feet and in the Oxford district at 240 feet. A further complication is involved, for writers who speak of a 'terrace at 100 feet' seldom explain whether it is the shelf of solid rock on which the gravel rests or the present surface of the gravel which is at 100 feet. Again consecutive numbering has frequently been used, but since the 100-feet terrace is spoken of alike as the first, the second, or the third, the interpretation of the literature is attended with much difficulty.

The need of a simple nomenclature is obvious, and in view of the attention which the subdivisions of the Palaeolithic period are attracting in England, it is tempting to make use of the French terms. The trend of evidence seems to indicate that the 130-foot and 100-foot terraces belong to the Chellean and Acheulean stages, and the 50-foot to the Mousterian; but in the area as yet mapped by the Survey the evidence for this correlation is scanty, and in the lower gravels of Upper Palaeolithic and later age there is everywhere great confusion due to a double sequence, downwards to the bottom of the buried river channel and upwards again to the present alluvium of Holocene age. For these reasons the adoption of local names for each area is preferable; so far as regards the areas included in Sheets 255 (Beaconsfield) and 269 (Windsor) of the New Series one-inch map the terms Boyn Hill Terraces and Taplow Terrace are convenient, the pits at both places being well-known, and identifiable even if future work should reveal higher or intermediate terraces.

At Boyn Hill there are an upper and a lower terrace, more or less distinct, which are stated by Mr. Ll. Treacher[1] to contain Palaeoliths of slightly different types so that a collection of implements from one pit would indicate with fair certainty in which of these terraces the pit was situated, though no single implement would suffice for this division. In other parts of the district the two terraces merge into a continuous slope. The

[1] *Proc. Geol. Assoc.*, vol. xxi (1909), p. 198.

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upper Boyn Hill terrace may with some certainty be correlated with the 130-foot, the lower with the 100-foot of the lower Thames Valley, but the term Boyn Hill Terraces will be used to describe features and deposits which may belong to either or both of these minor divisions.

The Taplow Terrace corresponds with the 50-foot, and in the area mapped is always separated from the Boyn Hill by an outcrop of solid strata. No such outcrop occurs between the Taplow and the lower gravels, though there is usually a distinct feature by which to separate them. These lower gravels have not been subdivided, and will be referred to, without prejudice as to their exact age, as 'flood-plain' gravels.

On the accompanying map (fig. 2) is shown the distribution of the various terraces between Virginia Water and Chertsey. The flood-plain gravels (lettered F.P. on map) form a wide spread of which part only is shown; they belong to the Thames which now follows a meandering course through them and just enters the map at the north-eastern corner, but the Boyn Hill and Taplow gravels (lettered B. and T. respectively) do not associate themselves with the Thames in their distribution; for they form a well-marked band diagonally across the map, separated from the Thames by the high ground of Callow and St. Anne's Hills, both of which are formed of Tertiary strata with little patches of Plateau gravel (not shown on the map). In them we may recognise the track of a river-course stretching from Virginia Water lake, just beyond the western corner of the map to Cockcrow Hill near Chertsey: but when we look for the stream which laid them down we find that the eastern half of the valley is dry. For the Bourne which flows along the western part suddenly abandons the line of gravels, and turns to the north between Callow Hill and St. Anne's, thence finding a course across the flood-plain gravels of the Thames.

From a detailed study of the limits of the respective terraces it is possible to reconstruct the history of this anomalous drainage. On the right bank of the Thames a well-marked river-cliff stretches from Old Windsor past Cooper's Hill and Egham, entering the map (fig. 2) near the north-western corner, and thence running in a characteristic curve to St. Anne's Hill: it is through this cliff that the Bourne now cuts a narrow valley on the way to the flood-plain. To the south and east of St. Anne's Hill past Chertsey to the mouth of the Wey there runs a second curve, much broken by recent denudation. At no point along this cliff do we find any trace of gravels belonging to either the Boyn Hill or the Taplow terraces; we may conclude therefore that it has been cut back to its present position since the deposition of the Taplow gravels.

The Boyn Hill and Taplow gravels are, however, well developed along the course already mentioned as running south of the Callow, St. Anne's and Sandgate Hills. Along this course there must once have flowed a considerable stream: for the Boyn Hill gravels, though now represented only by isolated patches, appear once to have extended more than a mile in width; on the other hand the Taplow gravels as a narrower belt are fairly continuous,

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FIG. 2.—Geological Map of the Bourne Valley. Scale, three inches = 2 miles.

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and associated with them there remains a considerable deposit of peaty alluvium which, where it lies to the south of Cockcrow and Sandgates, must be of approximately Taplow age, while the rest is not much newer.

Following upon the deposition of the Taplow gravels important changes took place. The Thames now flowing at a lower level undercut its right bank and encroached upon the Tertiary area until a way was opened for the passage of the flood waters of the Bourne between St. Anne's and Cockcrow Hills: the adoption of this new course now left Sandgates and Cockcrow Hills as outstanding islands, while St. Anne's still remained a part of the main mass.

As the planation by the Thames continued a new river-cliff was formed a little higher up stream. St. Anne's Hill is formed of Bagshot Beds of an unusually loamy facies capped by Bracklesham Clays with a thick pebble-bed and some plateau-gravel, whereas on either side of it the sands are loose; it has consequently resisted corrosion and now projects into the Thames flood-plain. On the north side of this projection the Bourne waters were again diverted, and the whole of the lower valley including the previous diversion was abandoned.

The effects of this change are noticeable both in the valley of the Bourne itself and in the upper part of the Lynegrove brook. Between the two points where it is crossed by railways the Bourne has obviously acquired an increased gradient, as a consequence of which the channel is deeper and the banks more abrupt than in the upper reaches where the change has not yet made itself felt. This deepening of the bed has laid open the Bagshot sand below the Taplow terrace, a feature not found anywhere else in the neighbourhood. Similarly the Lynegrove brook near Hersham Farm has cut a little notch in its old plain leaving minute terraces on each side. Where the Bourne reaches this Thames flood-plain it has spread out the material removed by its new activity as an expanse of alluvium which at first sight appears much too big for so small a stream.

As no implements have as yet been found in the Bourne gravels it is impossible to date the changes described above exactly, but the general sequence in the history of this curious bit of physical geography is clear.

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APPENDIX III.

Note on *Orthis carausii* (Salter MS.) Davidson and *O. calligramma*, var. *proava* Salter.

By Dr. C. A. Matley.

Orthis proava Salter.

1866. *Orthis calligramma*, var. *proava*, Salter. Mem. Geol. Survey, vol. iii, Geol. of N. Wales. Appendix, pp. 335, 336, pl. xxii, fig. 1. (Also p. 259 as *O. calligramma*, var. See also p. 258.)
1868. *Orthis Carausii*, Davidson. Geol. Mag., vol. v, p. 315, pl. xvi, fig. 23.
1869. *Orthis Carausii*, (Salter MS.) Davidson. Monogr. Brit. Foss. Brach., vol. iii, p. 229, pl. xxxiii, figs. 1-7.
1869. *Orthis calligramma*, var. *proava*, Davidson. Monogr. Brit. Foss. Brach., p. 241, pl. xxxv, figs. 13, 14, 15.
1873. *Orthis Carausii*, Salter. Catalogue of the Collection of Cambrian and Silurian Fossils in the Museum of the University of Cambridge, p. 24.
1883. *Orthis Carausii*, Davidson. Monogr. Brit. Foss. Brach., vol. v, pp. 182-184, pl. xiv, figs. 21-26.
1899. *Orthis calligramma*, var. *Carausii*, Matley. "On the Geology of Northern Anglesey," Quart. Journ. Geol. Soc., vol. lv, pp. 640, 641.

Orthis calligramma, var. *proava*, was described by Salter in 1866 from specimens obtained from "Upper Llandeilo Rocks, in grits among the black slates of Llanerchymedd, Anglesea." He considered the form to be separable from the typical *Orthis calligramma* as a variety, and to be "recognisable by its convex shape and square form, with a hinge line equal to the shell in width, a convex dorsal valve rather deeply lobed, and with 14 strong ribs longitudinally striate, the middle ones remote, the outer ones interlined and smaller. The internal septum is short and strong—the hinge teeth somewhat stouter than usual." It is unfortunate that the locality from which his type specimens were obtained was not stated with greater precision, especially as the whereabouts of the figured example is not known. On page 259 of his Appendix, however, Salter recognised the occurrence of this variety at the following localities: "One mile north-west of Llanerchymedd; Treiorwerth; and Tyn-twr, four miles south of Llangefni." He was also evidently writing of this form on page 258, where he mentions "the multitudes of a dwarf variety of *Orthis calligramma*, pl. 22, which give a Caradoc aspect to the grits." It is clear then that Salter intended the name *proava* to be applied to the *calligramma*-like form found abundantly in the Ordovician grits of Central Anglesey.

In 1869 Davidson, when describing *O. calligramma* in his monograph of British Silurian Brachiopoda, reproduced a portion of Salter's figure under the varietal name *proava*, but did not mention it in the list of varieties which he was prepared to recognise.

In 1880 Professor McKenny Hughes, in referring to the *Orthis* found abundantly in Anglesey in beds which he ascribed to a Tremadoc horizon, stated that the species was not *O. calligramma*, but "*O. Carausii*, a plano-convex shell of smaller size and with fewer ribs than *O. calligramma*, and a characteristic Tremadoc

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fossil."[1] In 1882 he referred again to this fossil as "*O. Carausii*, an Arenig or Tremadoc fossil," and expressed the further opinion that *O. carausii* is the same species as *O. hicksi*, a Menevian form.

In 1883 Davidson figured and described in detail a number of Hughes's examples from Ty-hen, near Treiorwerth, Anglesey, in the supplement to the British Silurian Brachiopoda. He pointed out that they differed essentially from *O. hicksi*, but accepted Professor Hughes's indentification as *O. carausii*, as he found that the specimens were exactly similar to the types which he had figured and described by that name in 1868 from Tremanhire, near St. David's. He also admitted the identity of Professor Hughes's specimens with the form figured by Salter in 1866 in the Survey Memoir, but evidently overlooked the fact that that form had been described in that volume under a name (*proava*) which takes priority of the name *carausii*.

The name *carausii* therefore becomes a synonym of *proava*, and the only question of nomenclature left to be decided is whether the form should be called *Orthis proava* or *Orthis calligramma*, var. *proava*. This point will now be considered.

The grounds on which *O. carausii* was separated from *O. calligramma* as a distinct species were (*a*) its smaller size and fewer ribs, and (*b*) its occurrence at a lower horizon (Tremadoc and Arenig) than *Orthis calligramma*, which, according to Davidson, ranges, with its varieties, from the Llandeilo to the Wenlock Series. The Central Anglesey fossil is now definitely known to be of Arenig age and to occur below the Zone of *Didymograptus bifidus*. It has from 14 to 20 ribs, usually 16 or 18, and rarely exceeds 17 millimetres in width, the majority of specimens being of smaller dimensions.

The type of *Orthis calligramma*, as described by Dalman in 1827,[2] was 24 mm. wide and had about 32 to 34 ribs, though Davidson in 1869[3] accepted as belonging to the species forms with from 16 to 50 ribs. There can be no doubt that the Anglesey and St. David's form is connected genetically with *Orthis calligramma*, but having regard to the stricter view of specific characters taken by palæontologists at the present day, it seems desirable to regard it as a distinct species, and to call it *Orthis proava*.

O. proava passes up into the Llandeilo Series, as I described the form in 1899 (under the name of *O. calligramma*, var. *Carausii*), from beds in Northern Anglesey which are almost certainly of Upper Llandeilo age. The only difference I could trace between them and the Ty-hen specimens was that on the whole they were of rather larger dimensions.

---

[1] 'On the Geology of Anglesey.' *Quart. Journ. Geol. Soc.*, vol. xxxvi., 1880, p. 238.

[2] *Kon. Vet. Handl.*, p. 114, pl. ii, fig. 3.

[3] Monog. Brit. Foss. Brach., vol. iii, p. 240.

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APPENDIX IV.

NOTES ON THE UPPER LIMESTONES OF THE BATHGATE DISTRICT.

BY M. MACGREGOR.

Since the publication of the Memoir on the Geology of the Edinburgh District in 1910, in which a short account of the Upper Limestones of Bathgate is given, additional information about this group has become available. It is thus possible to clear up a certain amount of confusion that existed in regard to the number of limestone horizons and to their correlation with the

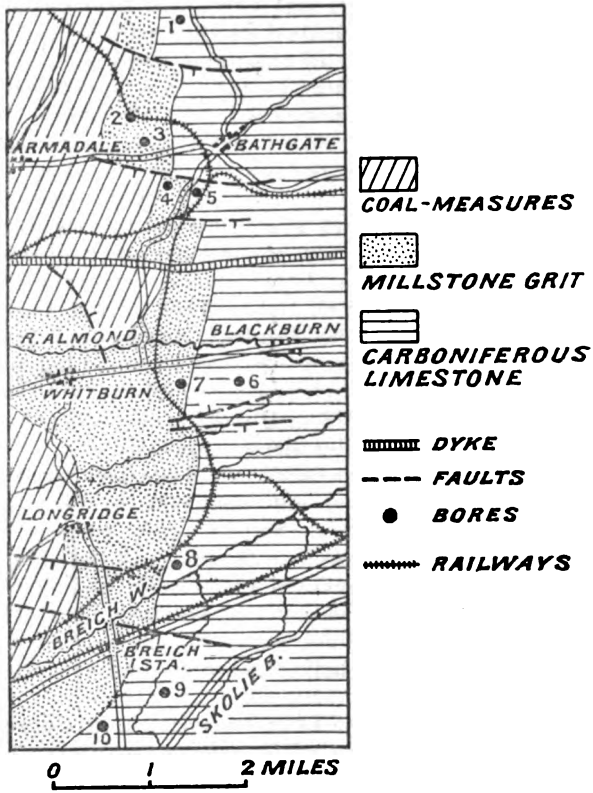

FIG. 3.—Map of the country around Bathgate, Blackburn and Breich.

Upper Limestones of the rest of Scotland. The object of this Appendix is to amplify and, in part, to correct information given in the Edinburgh District Memoir.

When that memoir was written it was believed that only three limestones are present in the Upper Limestone Group of Bathgate.[1]

[1] It was known, however, that in the same group near Linlithgow a 3-foot limestone, occurs between the Index and the Calmy Limestones. Its height above the Index was estimated as 250 feet, and there can be no doubt it is in the position of the Orchard Limestone of the following tables. *See* 'Summary of Progress' for 1904 (*Mem. Geol. Surv.*), 1905, p. 112.

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Unfortunately this led to the correlation of the highest limestone then known at Bathgate (the Calmy Limestone) with the Levenseat or Castlecary Limestone of the ground further south. Consequently, at different points along the strike of the rocks between Bathgate and Wilsontown, two bands, at least 46 fathoms apart, were taken to represent the upper limit of the Carboniferous Limestone Series.

In the Bathgate country there are four limestones present corresponding to the well-known Castlecary, Calmy or Arden, Orchard and Index Limestones of the west. The following table shows the relative positions of these limestones in a series of ten bores between Hilderston Farm, 1½ miles N.N.W. of Bathgate, and Handaxwood, 6 miles S. of Bathgate. Further analysis of these bores shows that, as in general in the Scottish coalfields, there is a very constant recurrence of a cycle of sedimentation in which sandstone succeeds to blaes, blaes to limestone, and limestone to coal. Over the Bathgate district the coals in the Upper Limestone Group are thin unworkable seams associated with blaes. Most of the horizons, known in the West of Scotland can be recognised, although no equivalent of the Lyoncross (or Holeburn) Limestone appears in any of the bores and, indeed, this bed is known to be poorly developed or absent all along the south side of the Lanarkshire coalfield. Between the Index and the Orchard positions there occurs a 9- to 19-inch seam of coal which possibly represents the Lyoncross Coal of the Arden basin. A thick post of sandstone corresponding to the Barrhead Grit in part and to the Bishopbriggs Sandstone overlies the Index in several bores, and in half at least of these a thin limestone or shelly band has been got above this sandstone in the position of the cementstone of the Bishopbriggs quarries.[1] The Giffnock Sandstone is represented by a series of sandstone and sandstone fakes, and the thick beds of blaes that overlie both the Orchard and Calmy Limestones are always well developed. A few thin coal seams occur in the position of the Hirst Coals. A thin limestone found in one bore a short distance below the Levenseat Limestone corresponds with a bed found locally in other parts of the Lanarkshire basin.

An interesting point brought out by these bores is the occurrence of a tongue of lava which stretches from Hilderston Farm south to near Mosshall. It lies 22 to 15½ fathoms above the Index Limestone and from 22½ fathoms thickness at Bathgate decreases gradually to a few feet at Mosshall.

The positions of the Limestone or Edge Coals are also indicated in the diagram; these include the Balbardie Gas, China, Smithy, Lady Morton or Jewel, Wilsontown Main and Wilsontown Gas. All of these have been more or less worked. None are constant in thickness over a wide area; they are very liable to be split up by ribs of sandstone, especially towards the southern part of the area. The chief seam is the Wilsontown Main, this being generally in several leaves separated by blaes or fireclay.

[1] A shelly band in very much the same position has recently been found by Mr. G. V. Wilson in the Bilston Burn, Mid-Lothian.

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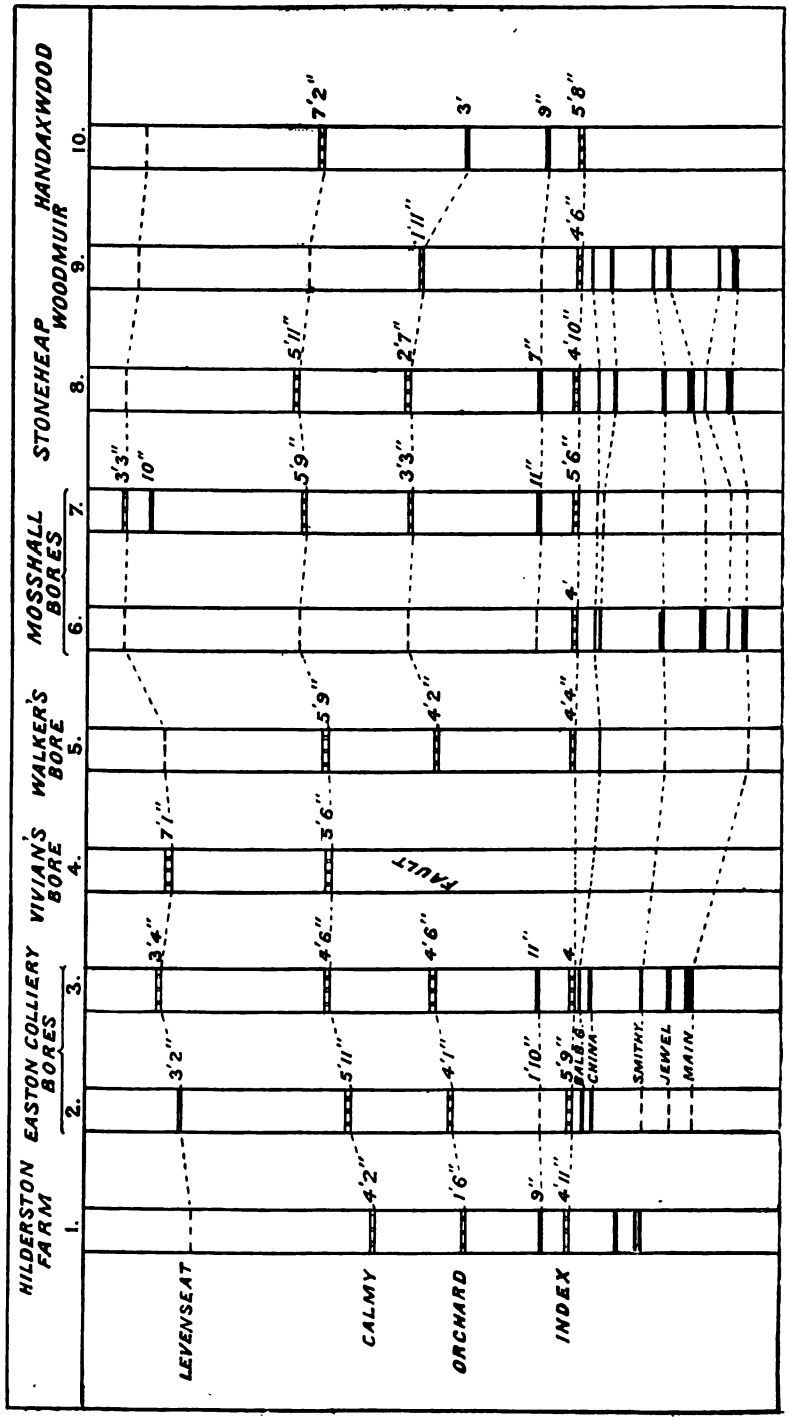

FIG. 4.—Vertical Sections of the Upper Limestone Group in the Bathgate and Breich District. Scale, 300 ft. = 1 in. The following thicknesses of lava are omitted:—Between the Index and Orchard Limests., in section (1) 22¾ fms., in (2) 22¾ fms., in (3) 19¼ fms., in (5) 12¾ fms., in (7) 5⅛ fms.; between Index Limest. and Balbaidie Gas Coal, in (2) 6¼ fms., in (3) 5¼ fms.

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The following table gives the average thicknesses of the various subdivisions of the Carboniferous Limestone Series throughout the area covered by the bores. It should be stated, however, that at Bathgate a large part of the succession below the Main Coal is replaced by contemporaneous igneous rocks.

	Fms.
Levenseat to Index Limestone	124
Index Limestone to Main Coal	36 to 45
Main Coal to Gas Coal, approximately in the position of the Kilsyth Coking Coal	24
Gas Coal to top limestone of Lower Limestone Group ...	44

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APPENDIX V.

NOTE ON FOSSIL PLANTS FROM GARRALLAN PIT SINKING, ½ MILE S.S.W. OF OLD CUMNOCK, AYRSHIRE. BY DR. R. KIDSTON, F.R.S.

Two collections of fossil plants from this Pit Sinking were submitted to me for examination.

The first was collected by Mr. John Smith of Dalry, and contained the following species.

Horizon:—33 fathoms above the "Maid" or "Splint Coal."

Sphenopteris sp.
Neuropteris heterophylla Brongt.
,, *obliqua* Brongt. sp.
,, *obliqua* Brongt. sp. *forma impar* Weiss sp.
,, *osmundae* Artis sp.
Calamites undulatus Sternb.
Asterophyllites equisetiformis Schl. sp.
Lepidodendron sp.
Samaropsis sp.

The other collection was made by Mr. A. Macconochie of the Geological Survey of Scotland and was derived from the following horizon.

Horizon:—Shale lying below the "Ell Coal" (the highest seam).[1]

Pecopteris cf. Miltoni Artis sp.
Dactylotheca plumosa Artis sp.
Odontopteris sp.
Neuropteris heterophylla Brongt.
,, *obliqua* Brongt. sp.
,, *Scheuchzeri* Hoffm.
Calamitic coal.
Asterophyllites equisetiformis Schl. sp.
Annularia sp.
Sphenophyllum cuneifolium Sternb. sp. *var. saxifragæfolium* Sternb. sp.

For the purpose of determining the age of the rocks from which these fossils were derived, the two lists may be treated together, as they indicate a similar horizon, and the following table shows their distribution in the Westphalian and Lanarkian Series, the only divisions of the Upper Carboniferous with which a comparison is admissible.

Garrallan Pit Sinking.	Westphalian Series.	Lanarkian Series.
Sphenopteris sp.		
Pecopteris cf. Miltoni Artis sp.	×	
Dactylotheca plumosa Artis sp.	×	×
Odontopteris sp.	×	

[1] [No more precise information could be obtained regarding the exact position of the plants collected by Mr. Macconochie. The 'Ell' Coal lies some 60 fms. above the 'Maid.' The plants collected by Mr. Macconochie are consequently from a position between those two coals, but whether from the same bed as those collected by Mr. Smith cannot be proved (G. W. Lee).]

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Garrallan Pit Sinking.	Westphalian Series.	Lanarkian Series.
Neuropteris heterophylla Brongt.	×	×
,, *obliqua* Brongt. sp.	×	×
,, *obliqua* Brongt. sp. *forma impar* Weiss sp.	×	×
,, *osmundae* Artis sp.	×	
,, *Scheuchzeri* Hoffm.	×	
Calamites undulatus Sternb.	×	×
Calamitic cone		
Asterophyllites equisetiformis Schl. sp. ...	×	×
Annularia sp.		
Sphenophyllum cuneifolium Sterb. *var. saxifragæfolium* Sternb. sp.	×	×
Lepidodendron sp.		
Samaropsis sp.		

Of the nine species which could be specifically determined, all occur in the Westphalian Series and six in the Lanarkian Series, but if one examines more minutely into the relative frequency of the species in the two Series to which they are common, the pronounced Westphalian facies of the beds which have yielded these plants is very strong.

Pecopteris cf. *Miltoni* Artis sp.

Although this species is queried in the list, I am almost certain that the specimens found belong to this plant. *Pecopteris Miltoni* is common in the Westphalian Series, and may be regarded as one of its most characteristic species, though it extends upwards into the Radstockian Series. On the other hand, I have never seen any specimen I could identify as this species from the Lanarkian Series.

Dactylotheca plumosa Artis sp.

Though this has been met with in the Lanarkian Series it is extremely rare on that horizon, where not more than a couple of specimens have been found, as far as I am aware. In the Westphalian Series, however, of Great Britain, it is one of the most characteristic species.

Odontopteris sp.

Though the species to which this imperfect specimen belongs could not be determined, the occurrence of the genus *Odontopteris* is of interest, for as far as I am aware it has never been recorded from the Lanarkian Series, whereas in the Westphalian Series a few species occur.

Neuropteris heterophylla Brongt.

This is common to both Lanarkian and Westphalian Series, and as far as these two divisions are concerned is not a " zonal " form.

Neuropteris obliqua Brongt. sp.

Though this species occurs rarely in the Lanarkian Series it is very frequent and characteristic of the Westphalian Series, and forms one of its most characteristic species. The plant was very plentiful at Garrallan, and out of a collection of fifty-five specimens sent for examination by Mr. John Smith, 30 belonged to *Neuropteris obliqua*.

Neuropteris osmundae Artis sp.

This species is restricted to the Westphalian Series.

Neuropteris Scheuchzeri Hoffm.

Though this plant is characteristic of the Staffordian Series and Radstockian Series, it occurs occasionally in the Westphalian Series; it does not, however, pass below that division.

Calamites undulatus Sternb.

This species is common to both the Lanarkian Series and the Westphalian Series, and is not of " zonal " value in either of these horizons.

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Asterophyllites equisetiformis Schl. sp.

This also is not of " zonal " value, as it extends throughout the whole of the Upper Carboniferous Rocks.

Sphenophyllum cuneifolium Sternb.

This Sphenophyllum is common to both the Westphalian Series and the Lanarkian Series, and is not of " zonal " value in these rocks.

To sum up, of the ten species occurring at Garrallan—for we may include for the purpose of comparison the *Odontopteris* sp., for the reason already stated—all are well-known Westphalian plants though six of them occur in the Lanarkian Series, but of these six, *Dactylotheca plumosa* has only hitherto been found once, or twice at the most, in the Lanarkian Series, and though *Neuropteris obliqua* has been discovered in the Lanarkian more frequently, both are essentially Westphalian species, so that for practical purposes the proportion of Westphalian species to Lanarkian species is ten to four, showing, I think without doubt, that the Garrallan beds must be referred to the Westphalian Series.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1912.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1912.

I.—*INTRODUCTION.*

By J. J. H. Teall, M.A., Sc.D., F.R.S., Director.

During the year 1912 the primary six-inch Survey of England and Wales has been continued on the same lines and in the same districts as in the previous year. These districts are known as (1) the Denbighshire District, (2) the Warwickshire and Staffordshire District, and (3) the London and South-eastern District.

In the Denbighshire District, in which are included parts of Flintshire and Cheshire, progress has been made with the surveying of the Coal Measures and also of the older and newer rocks which come within the limits of the New Series One-inch Ordnance Maps in which the Coalfields occur.

In the Warwickshire and Staffordshire District the survey of the northern portions of the visible coalfields of Warwickshire and South Staffordshire has been completed as well as that of the intervening area occupied by the New Red Sandstone formation.

In the London and South-eastern District work has been carried on in Berkshire, Buckinghamshire, Hertfordshire, Middlesex and Surrey. The Aylesbury Sheet has been completed, and field-work is now proceeding in the London area. A Memoir on the water-supply of London from underground sources (Records of London Wells) was in the press at the end of the year and has since been published. The subject dealt with is of special interest at present in view of the fact that the amount of water drawn annually from the Chalk under London, which has for many years past been in excess of the amount passing into that formation, is increasing; so that the lowering of the water-level and the consequent depletion of this valuable reservoir is progressing at an increasing rate.

Brief references to the various geological formations on which work has been done during the year will now be made.

Crystalline Schists and their associated Igneous Rocks.

The original survey of the Highlands of Scotland has proceeded on the usual lines. In East Sutherland and Ross the

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sedimentary schists with their associated igneous rocks have been surveyed and additional phenomena illustrative of "granitisation" have been observed.

In the Lochaber District, east and south of Ben Nevis, the complicated tectonic features are engaging the attention of the Surveyors, and, although no serious difficulty arises in tracing the boundaries of the different lithological groups, general agreement has not been reached as to the interpretation of the facts which have been brought to light. The surface distribution of the different lithological types is being satisfactorily recorded on the maps; but until more is known of the form, extent, and relative position of each of the original rock-sheets, extended sections drawn across the district must be highly speculative and so far as the broad general features are concerned can only be regarded as working hypotheses.

Lower Palæozoic Rocks.

The mapping of the Ordovician and Silurian rocks which lie to the west of the Denbighshire Coalfield has been continued and considerable tracts, both north and south of the Dee, have been surveyed for the first time on the six-inch scale. Several new subdivisions have been recognised and their boundaries traced. The general features of the geology as recorded on the old map have been confirmed, except that no unconformity has been detected at the base of the Tarannon. The igneous rocks associated with the Ordovician strata have not as yet been fully examined. Some of them are rich in soda and of keratophyric habit.

The detailed mapping of the Cambrian rocks on the east side of the Warwickshire Coalfield and of the Silurian rocks of the Walsall inlier (Staffordshire) has been continued.

Old Red Sandstone Rocks.

The outliers of Old Red Sandstone which lie to the west of Forsinard in East Sutherland have now been completely surveyed. Their general characters have been described in the Summary of Progress for 1909.

Carboniferous Rocks.

In the Warwickshire and Staffordshire District the tracing of the boundaries of the Etruria Marls, the Halesowen Sandstones and the Keele Beds, all of which overlie the productive Coal Measures has made much progress. Many new occurrences of the thin bands of *Spirorbis*-limestone which characterise the Halesowen and Keele groups have been noted, and amongst them some which prove that the sandstones and marls of a large tract near Tamworth, hitherto regarded as Keuper Sandstone, must now be assigned to the Keele Beds. The unconformable super-position of the true Keuper upon them has been exposed to view.

In Warwickshire the mapping of the Coal Measures has been continued southwards, the unconformable junction with the Cambrian rocks has been traced for some distance and a complete

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section of the Lower Grey Measures, which alone contain workable coal seams, has been constructed. The general conclusions arrived at during the first survey, more than fifty years ago, as to lateral changes in the productive measures in a north and south direction have been confirmed.

In Denbighshire and Flintshire the work of mapping the Coal Measures has proceeded. Three stratigraphical divisions are recognised to which the terms Lower, Middle and Upper have been applied. Workable coals are confined to the Middle division. The most important result of recent work in this area has been the recognition of an unconformity at the base of the Upper Barren Measures. The unconformity cannot be seen at the surface but pit-sections show that in the neighbourhood of Flint the upper part of the productive measures containing the main-coal is absent; red measures belonging to the upper group there resting directly on lower members of the middle group.

In Scotland the revision of the Carboniferous areas has proceeded in South Lanarkshire and North Ayrshire and it is evident that some important modifications which will render more accurate our knowledge of the boundaries of the coalfields and of their structure will have to be made in the old maps. Evidence of an unconformity in the Millstone Grit has been obtained in South Lanarkshire. This is of some general interest for although it has long been known, from the researches of Dr. Kidston and the late Dr. Traquair, that an important palæontological break occurs at this horizon in other parts of Scotland, no actual unconformity has been hitherto detected.

Permian Rocks.

The strata now known as the Keele Beds and classed with the Carboniferous are represented as Permian on the old-series maps. It follows as a consequence of this change in classification that in Warwickshire and South Staffordshire, as in North Staffordshire, much of the Permian of the old survey is being relegated to the Carboniferous. In the Warwickshire area no upper limit to these Keele Beds has yet been met with; but in South Staffordshire the discovery of footprints of Rothliegende reptiles by Mr. Hardaker in the Hamstead quarries suggests that a line should be drawn between Carboniferous and Permian at a height of about 900 feet above the base of the Keele Beds in that district where certain conglomeratic beds make their appearance. The progress of the work will show how far this line is traceable on the maps; but up to the present no evidence of unconformity at this horizon has been found.

Triassic Rocks.

An area of Trias, largely concealed by Drift, has been surveyed in the Wirral peninsula of Cheshire, between the estuaries of the Dee and the Mersey. The three divisions of the Bunter, Lower Mottled Sandstone, Pebble Beds and Upper Mottled Sandstone, established by Prof. Hull at the time of the earlier survey have been mapped with some slight modification of the original

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boundary lines. Only a small portion of the Keuper area, composed mainly of the Basement Beds which are so well-exposed in the celebrated quarries at Storeton, has as yet been surveyed.

In the Warwickshire and South Staffordshire District the mapping of the broad belt of Triassic rocks lying between the two coalfields has been continued. Some work has also been done on the east side of the Warwickshire coalfield where an outlier of Keuper Sandstone, not hitherto recorded, has been met with.

The Hopwas conglomerate or breccia has now been traced over a large area and its relationship to the other rocks of the district ascertained. Its outcrop is not continuous but when the rock is present it occurs at the base of the Bunter with which formation it appears therefore to be closely associated. It is not affected by the pre-Triassic earth movements and is therefore more closely related tectonically with the Trias than with the red measures, overlying the Keele Beds, in which foot-prints of Rothliegende reptiles have been found.

Jurassic Rocks.

The only Jurassic Rocks surveyed during the year form the promontory and base of the cliffs south-west of Port Ohirnie, two and a half miles south of Loch Buie (Isle of Mull). They include Lower and Middle Lias. The now celebrated Raasay ironstone which occurs in the Middle Lias is not present at this locality. In addition to actual mapping attention has been paid to the sequence of life-zones in the Jurassic rocks of Mull. The general results of this investigation are recorded in the palæontological part of this Summary.

Cretaceous Rocks.

In the London and South-eastern District a considerable area of Chalk has been mapped in the counties of Buckinghamshire, Hertfordshire, and Surrey. The work has proceeded on the usual lines. In tracing the horizon of the Chalk Rock local patches of highly fossiliferous nodular chalk containing lumps of phosphate have been noticed in a few places. It is suggested that the nodules formed strong patches on a sea bottom, elsewhere consisting mainly of soft mud, and that "this may be the explanation of the striking concentration on such spots of the crawling animals, such as gasteropods and cephalopods, and also of the exceptional abundance and variety of many organisms which require a solid base on which to fix themselves."

Tertiary Rocks.

The recognised subdivisions of Eocene strata have been mapped both south and north of the Thames. In last year's Summary it was pointed out that certain evenly bedded sands and clays occurring near Claygate in Surrey form a transitional series between the London Clay and the overlying Bagshot Sands. The

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mapping of these Claygate Beds, as they have been called, has been continued in Richmond Park and about Wimbledon Common.

In Scotland progress has been made with the survey of the Tertiary igneous rocks of the island of Mull. The structure of the interior is of the highest complexity and great care is necessary in unravelling the relations of the volcanic and intrusive rocks. Facts are accumulating as to the relative ages of different petrological types, as to the recurrence of similar types and as to the forms and tectonic relations of the different rock-masses, but it is not yet possible to construct a connected story. The great Breccia which forms so conspicuous a feature in the geology of south-eastern Mull has been further investigated; but no definite conclusion as to its origin has as yet been reached.

One of the most interesting results of the recent work in Mull has been the discovery of numerous small hexagonal plates of blue corundum (sapphire). Details as to their mode of occurrence will be found in the following pages.

Pleistocene and Recent.

Large tracts of the area surveyed in the Denbighshire District are covered by glacial deposits consisting of red boulder clay, usually containing fragments of marine shells, and stratified masses of sand and gravel. In the Flintshire area some physiographic features of considerable interest are being studied in connection with the mapping of these deposits. Thus it can be shown that the courses of the streams after leaving the high ground have been largely determined by the events of the glacial period.

The surveying of the Drifts in the Warwickshire and Staffordshire District has been continued and some further information as to the distribution and character of the two types—the Western and the Eastern—will be found in the following pages.

The Drift deposits of the London area, occurring as they do on the borderland between glaciated and non-glaciated regions, present problems of great interest and complexity. Boulder Clay, Clay-with flints, Brick-earths and Fluvio-glacial Gravels, though separable in a general way, seem in parts of the area to be more or less interchangeable terms. Masses of disturbed and reconstructed Eocene-material, which are sometimes most difficult to distinguish from Eocene-in-place have been met with. Opportunity has been taken to examine in conjunction with the British Museum some excavations in implement-bearing high-level gravels at Swanscombe. The results so far as geology is concerned are described in an Appendix.

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II.—FIELD WORK.

(A.) ENGLAND AND WALES.

The geological surveying of the three districts which were commenced in 1910 has been continued, namely:—

1. Denbighshire District under Mr. G. W. Lamplugh.
2. Warwickshire and Staffordshire District under Mr. G. Barrow.
3. London and SE. District under Mr. C. Reid.

Much additional information has at the same time been gathered with respect to deep borings made in search of coal to the east of the proved Yorkshire Coalfield, in the Midlands and elsewhere outside the areas which are being surveyed.

1.—Denbighshire District.

Mr. G. W. Lamplugh, F.R.S., District Geologist.
Mr. C. B. Wedd, B.A.
Mr. B. Smith, M.A.
Mr. L. J. Wills, M.A.
Mr. W. C. Simmons, B.Sc.
Mr. W. B. R. King, B.A.
} Geologists.

The field-work of the year consisted in the survey on the six-inch scale of the Older Palaeozoic rocks to the westward of the Denbighshire Coalfield for the completion of the Wrexham Sheet (121), along with the revision of the Flintshire Coalfield and the contiguous country in the Flint (108) and Liverpool (96) Sheets of the one-inch map.

ORDOVICIAN.

Besides mapping a small tract of Ordovician rocks on the northern slope of Cyrn-y-brain, Mr. Smith surveyed the faulted inlier of this age forming Mynydd-Cricor, at the head of the Vale of Clwyd. This tract, rising to over 1100 feet O.D. has the structure of a broken dome, faulted on the north and west but with steeply dipping beds on its flanks in other directions. The beds are cleaved gritty fossiliferous mudstones with a local and variable development of grits in the higher layers. It is possible that these grits may prove to belong to the lower portion of the overlying Silurian sequence, as Llandovery rocks, previously unseparated, are certainly present in the area; but this point remains in suspense until the palaeontological material has been worked out. The grits are greenish-grey, fairly coarse and much banded with laminæ of mudstone; with these associated mudstones, their outcrop attains fully 90 yards in width, and the dip averages 35°. Where the grit-bands are thin, cleavage-pressure has caused the layers to be split up into phacoidal pieces, elongated in the direction of cleavage.

In the Glyn Ceiriog district Mr. Wills continued his work to the west of the valley and across the upland which holds the

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watershed between the feeders of the Dee and the Ceiriog. This tract is composed of Ordovician and Silurian rocks, structurally forming the southern limit of a syncline which has a gentle eastward pitch and a roughly east-and-west axis passing a little to the south of Llangollen. North of the axis lies a disturbed belt in which the beds have high and variable dips; but south of it, as a rule, the dips are comparatively low, rarely exceeding 20° or 30° and with a prevalent direction to a little E. of N., except in the western part of the district and as the axis of the fold is approached. The regularity of the dip over an area measuring 4 miles across the strike and 8 or 9 miles along it, is remarkable in view of the well-cleaved state of the rocks. All the rocks capable of being affected have been cleaved and the strike of the cleavage is almost constant at about E. 20° S., while its dip is usually low and northerly.

The structure of the country is well displayed by the outcrop of the Llandovery-Tarannon group. This crop can be traced with an approximately W. 20° N. course from where it emerges from below the Carboniferous rocks in the east to near Moel-Fferna, where it swings round in compliance with the pitch of the syncline to a roughly NW. strike. This change of strike affects only the Silurian and upper part of the Ordovician sequence, for the lower part at first preserves the E. 20° S. strike and then tends to turn towards an E.-W. direction or even towards a point somewhat south of west. The old series map displays this structure, though less definitely, as the 'Tarannon Shale' is mapped as unconformable on the 'Caradoc or Bala.' In reality the Llandovery is represented between these two groups and no evidence has been found, in the district surveyed, that an unconformity exists.

The mapping has necessitated the modification in detail of the outcrops, especially those of the ash-bands, and has led to the representation of subdivisions not shown on the old map. The Bala and Llandovery succession in Glen Ceiriog has been recently described by Messrs. Groom and Lake,[1] and their subdivisions and mapping of the rocks have been for the most part confirmed and adopted in the present survey, though with some reservation in respect to their classification, which cannot be put to the test until the palaeontological material has been further studied.

The following upward sequence has been mapped in this district:—

Beds below the Cwm Clwyd Ash.—Unfossiliferous sandy shales, blue shales and sandstones; in one or two places metamorphosed into spotted slates, presumably by intrusions of diabase.

Cwm Clwyd Ash.—A pink or grey or grey-blue ash, often fine-grained and compact, but sometimes coarse-grained; characteristically well- and thin-bedded; but thick-bedded bands always present. Near Glyn Ceiriog at least 180 feet thick, but thinner to the west.

[1] T. Groom and P. Lake. The Bala and Llandovery rocks of Glyn Ceiriog *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, pp. 546–595.

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Teirw Beds.—On the whole, a gritty series, some 1200-1300 feet thick. Near Glyn Ceiriog the upper part is composed of sandy shales or mudstones with thin sandstone bands and occasional thin ash and agglomerate beds; the lower part, chiefly coarse sandstone. Further west, near the Swch gorge, a thick ash-horizon is met with which can be traced to the edge of Sheet 121. The Teirw Beds, though fossiliferous near Glyn, have not yet yielded fossils in the western part of their outcrop. *Trinucleus concentricus* is common.

Pandy Ash.—A less well-bedded ash than the Cwm Clwyd Ash; otherwise rather similar to it. Part is extremely compact and white, and is being quarried at Pandy as 'China-stone' and for 'silica.' Its outcrop is traceable to the edge of the map. It is an acid rock, keratophyric in composition. It varies greatly in thickness, from about 80 to 10 feet.

Bryn Beds.—Dark blue slates and sandy mudstones and sandstones, often highly fossiliferous; may be 400 or 500 feet thick in the east, but are considerably thinner to the west. Near their base at various points occurs a sill of acid keratophyric composition, which has been extensively quarried at Coed-y-glyn near Glyn Ceiriog for road-metal. It is here about 50 feet thick.

Pen-y-graig Ash.—Presumably belongs to the upper part of the Bryn Beds, but is of impersistent distribution, occurring as lenses below the Dolhir beds near Glyn Ceiriog and below the black graptolitic slates to the west.

Blaen-y-cwm Beds.—Dark-coloured, soft, poorly-cleaved, graptolitic slates. They occur only to the W. of the Glyn valley, but have been traced nearly to the edge of the map. Presumably they represent part of the Dicranograptus Shales of South Wales.

Dolhir Beds.—Usually earthy-looking, sandy, ill-cleaved mudstones, full of fossils. The basal part towards the west is not readily distinguished from parts of the Blaen-y-cwm beds below. In the Glyn district there is a thin limestone developed near the base. They are thicker in the west than in the east. The thickness near Glyn appears to be about 700 feet.

Glyn Grit.—Apparently conformable to the Dolhir beds; very variable in thickness and composition. East of Glyn Ceiriog it becomes a limestone with grit-bands and is about 20 feet thick. West of the village it quickly swells out to about 150 feet, as shown by Messrs. Groom and Lake, and is a thin-bedded very tough fine-grained grit. Further west a thick-bedded coarser grit comes in at the top, and this has been traced as far as Moel-Fferna, though the thin-bedded variety has apparently become more shaly and indistinguishable from the Dolhir beds.

SILURIAN.

In the Cricor district Mr. Smith notes that rocks of undoubted Llandovery age overlie the broken dome of Bala rocks of Mynydd-Cricor with apparent conformity. They consist chiefly of 500–600 feet of cleaved blue mudstones of a medium tint; frequently with streaks or subangular specks or blotches of a darker type of

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mudstone. Bedding-planes are only occasionally distinguishable and fossils are scarce; but in one exposure beds of a more shaly type yielded Lower Llandovery graptolites.

The Llandovery mudstones are followed by some 1200 feet of pale rocks of Tarannon age, the Upper Llandovery being apparently absent in this district.

Tarannon shales also form the low ground on the north-west side of Cyrn-y-brain, enclosed in the angle where the Llanelidan and Bala faults part company. On the west a small fault separates them from the *Cyrtograptus murchisoni* zone of the Lower Wenlock.

The bulk of the Tarannon Beds are fine-grained smooth, pale blue-grey or blue-green, cleaved mudstones or paste-rocks, with a brown manganese stain or dendritic marking. They are sometimes slightly calcareous, and are unfossiliferous except where they contain thin stripes of darker blue mudstone which yield numerous graptolites. Fossils of the *Monograptus turriculatus* zone were found near Cyrn-y-brain and of the three higher Tarannon zones near Cricor, the uppermost, or *M. crenulatus* zone, comprising beds whose lithology is a passage type between Tarannon and Wenlock. Immediately beneath this zone the colour of the rocks is sometimes distinctly blue.

The Bryneglwys valley, the north-western slopes of Llantysilio Mt., and the uplands between Bryneglwys and Llanelidan, were mapped by Mr. Smith, who found them to be chiefly composed of graptolite-bearing rocks of Wenlock-Ludlow age, with rather high dip and a complex structure which will be better understood when the fossil-evidence has been more fully studied.

The Wenlock-Ludlow rocks form a somewhat monotonous series of flags and shales, with thin sandy laminæ clustered so as to form bands, the whole being cleaved more or less in proportion to the amount of muddy, silty, or sandy matter present.

The ground between the Tarannon shales of Cricor and Cyrn-y-brain is chiefly occupied by cleaved shales of the *C. murchisoni* zone, and this zone also overlies the Tarannon slates of Cricor, but is faulted against Lower Ludlow rocks north of Bryneglwys.

Nearly two miles north-west of Bryneglwys, Wenlock (Pen-y-Glog) grits, with intercalated shales, appear in force from beneath an overthrust in which Llandovery-Tarannon rocks are involved. The incoming of the grits is rather sudden, and is well-shown in another faulted mass nearer Bryneglwys (Jubilee Plantation) where the passage from typical Wenlock shales into gritty shales and beds of grit, with an individual maximum thickness of 6 feet, is very evident. These grits were not recorded upon the Old Series one-inch map. In the direction of Llanelidan they pass upwards into rocks which may represent the uppermost Wenlock shales, for higher beds in that direction seem, upon fossil evidence, to be near the Wenlock-Ludlow junction.

Wenlock grits were also mapped on the western margin of Sheet 121. At this point, also, they are faulted against pale Tarannon shales, both being bounded on the north by the Bala fault.

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North of the Llanelidan fault and east of the Vale of Clwyd the *M. nilssoni*, *M. tumescens* and *M. leintwardinensis* zones of the Lower Ludlow have been recognised in ascending order on the south-western flanks of Moel-yr-acre.

In the country south of the Dee valley the Fron-Frys Slates, claimed by Messrs. Groom and Lake to be of Llandovery age, were mapped by Mr. Wills from the east of Glyn Ceiriog to the flanks of Moel-Fferna. Where typically developed, they consist of speckled green-grey or blue-grey fine-grained cleaved mudstones or slates, similar to those found by Mr. Smith to the north. They differ very greatly however in thickness being only some 80 feet thick at Glyn Ceiriog as against the 500-600 feet seen at Mynydd-Cricor. In the southern district they are sometimes gritty slates, and towards the base have thin grit bands constituting an upward passage from the Glyn Grit. No graptolites have yet been found in this division.

The Ty-draw or Tarannon Slates which come next in upward succession are composed of a finer-grained and smoother 'paste-rock' of a more uniform pale green-grey colour which is not affected by weathering. Occasionally the beds have blue stripes, and near the top are sometimes predominantly blue.

In the eastern part of the district these blue upper beds (*Monograptus crenulatus* zone) are well developed, but they are not seen west of Glyn Ceiriog until Moel-Fferna is approached. This may imply the cutting out of part of the Tarannon group by strike-faulting. Further evidence may be seen in the Cambrian Slate Quarry at Glyn, where a level shows considerable disturbance and quartz-veining in the pale shales to which basal Wenlock beds succeed directly. Again, at the head of the Ty'n-y-twmpath stream the apparent passage up from the grey Tarannon to the blue Wenlock slates by interbedding may be deceptive if the crenulatus-zone be cut out by faulting. In the general absence of fossils, however, certainty on this point cannot be attained. It may be pointed out that it is highly probable that part of the series is missing at Glyn, for its total thickness there is less than 150 feet, in contrast to the 1200 feet observed in the Cricor district.

In the sequence of the Wenlock-Ludlow series as described in the last 'Summary of Progress,'[1] it is now found that the lowest division there given must be subdivided into a lower slaty portion and an upper flaggy portion, of which the latter will probably prove to be of Lower Ludlow age.

Part of the lower slaty beds are quarried for roofing slates at four places and constitute the Pen-y-glog slates.[2] The tip-heaps at Penarth (Pen-y-glog) and at the Moel-Fferna Slate Quarry have yielded good specimens of the problematic plant *Berwynia carruthersi* Hicks, and graptolites.

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[1] 'Summary of Progress' for 1911 (*Mem. Geol. Surv.*), 1912, p. 7.

[2] The terms here used are those adopted by Mr. Lake, 'The Denbighshire Series of S. Denbighshire,' *Quart. Journ. Geol. Soc.*, vol. li, 1895, pp. 9–23 : and by Miss Elles, *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, pp. 370–414.

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The Pen-y-glog Grit comes in very suddenly about 1 mile east of Moel-Fferna and its presence above the slates quarried at Moel-Fferna suggests that these slates are on the same horizon as those at Penarth, but the palæontological evidence on this point has not yet been worked out. This may affect the value of Mr. Lake's subdivision "Moel-Fferna Slates," but apart from this, the sequence he put forward appears to be well-founded, though no lithological divisions except the grit can be accurately mapped.

FAULTING AND CLEAVAGE IN THE LOWER PALÆOZOIC ROCKS.

The Bala Fault, and the Llanelidan Fault which diverges from it near Llandegla,[1] were traced by Mr. Smith to the western limits of the sheet. The Bala Fault, after skirting the NW. slope of Cyrn-y-brain, is concealed beneath glacial and alluvial deposits in the Bryneglwys valley, but appears again at the western border of the map, separating Wenlock grits and Tarannon slates from younger rocks on the north-west.

Between these two dominant faults there is a set of faults chiefly with a N.–S. trend. In the Cricor dome, where the lithology assists in their detection, they seem to be of the same age and character as those in the Carboniferous Limestone trough at the head of the Vale of Clwyd.[2]

Thrust-planes, with an easterly dip, which also occur in this area, are doubtless due to the differential resistance to pressure of the Wenlock grits and the underlying slates.

In the Dee valley Mr. Wills found that the beds are very disturbed and that within certain narrow belts which run nearly E. and W. the dips are extremely high. Between these belts the rocks have a different strike and gentle dips. The meaning of this has not been deciphered in the small area at present mapped.

Fairly numerous transverse faults have been traced in the ground S. of the Dee valley. Their strike is as a rule a little west of north and they generally throw down east. A few strike faults have been found and probably more occur, but in the absence of the repetition of the grit- and ash-bands they have not been detected.

It is not proposed to discuss the Cae-mor Fault described by Messrs. Groom and Lake[3] except to say that there is certainly a north-and-south fault which moves the outcrop of the Glyn Grit on its eastern side about one mile to the S. from near Dolywern. On the old map the outcrop of the Tarannon shale takes a sharp bend to the south near Dolywern, but the evidence is overwhelmingly against this interpretation of an obscure area and in favour of regarding the position of the exposed outcrops as due to faulting.

The behaviour of the cleavage in the two districts mapped is somewhat different. Mr. Smith found in the area to the N. and NE. of Llantysilio Mountain that where the rocks are undisturbed

[1] 'Summary of Progress' for 1910 (*Mem. Geol. Surv.*), 1911, p. 10.
[2] 'Summary of Progress' for 1910 (*Mem. Geol. Surv.*), 1911, p. 10.
[3] T. Groom and P. Lake *op. cit.* pp. 585–587.

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by post-Carboniferous faults the average cleavage-strike is about W. 10° N. to E. 10° S. whilst the dip of the cleavage varies from 30° to 60° in a northerly direction. From this it may be argued that there is a general absence of post-cleavage and pre-Carboniferous folding.

In the area between Mynydd-Cricor and Cyrn-y-brain where the rocks are disturbed by the Cricor, Llanelidan and Bala faults, the cleavage-strike is sometimes swung round into a NNW. and SSE. direction while the dip may be either to E. or W. at a high angle. Similar disturbances in cleavage-strike may generally be taken as reliable evidence of faulting.

South of the Dee valley Mr. Wills found a persistent cleavage-strike of about W. 20° N. and E. 20° S. The dip of the cleavage is northerly and as a rule low—in the Glyn Slate Quarries about 25°, but varies elsewhere up to 60°. Marked change of the cleavage-strike as an effect of faulting has only once been noted by him.

MILLSTONE GRIT.

Considerable rectification of the boundary shown on the old map between the Millstone Grit and the Lower Coal Measures has been found necessary by Mr. Lamplugh in the district north-west of Mold, and also in the country south-east of Mold, particularly in the neighbourhood of Pontblyddyn, surveyed by Mr. Lamplugh and Mr. King. Mr. King likewise notes that the grits exposed at Pen-y-mynydd, 2 miles south of Hawarden, which have been classed as Lower Coal Measures, are in all essentials similar to the rocks mapped as Millstone Grit on the northern flanks of Hope Mountain.

LOWER COAL MEASURES.

In surveying the north-western part of the Flintshire Coalfield Mr. Wedd finds, in respect to the lowest part of the Coal Measures, that as the outcrop of the Holywell Shales passes south-eastwards from Holywell to Halkin it affords evidence of lithological change, affecting the greater part of the group, but perhaps chiefly the lower half. No complete section of these beds is exposed, but the numerous outcrops in the dingles display many beds of fine-grained quartzitic and other sandstones and gannisters. These appear to become more numerous south-eastwards, and below Halkin are sufficiently numerous to modify the whole character of the division. In fact one group of them was mistaken on the old Survey map for the outcrop of the Gwespyr Sandstone. In a dingle east of Halkin the upper part of the Holywell Shales still consists chiefly of dark shale and contains black muddy limestone-bands associated with black shales containing goniatites. But these beds pass down into shales containing thin sandy limestones and fine-grained calcareous sandstones, while lower shales contain numerous beds of gannister and quartzite and some softer sandstones. Several faults obscure the sequence, but it appears that these lower sandstones are still associated with black, dark-blue and grey shales and black limestone-bands with goniatites. There is evidence that the

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sandstones here continue downwards nearly to the base of the group, *i.e.*, nearly down to the grit which has partly replaced the chert of the Millstone Grit Series.

The goniatites most frequently met with belong to the genus *Glyphioceras* and the group of *G. phillipsi*, but in the lowest beds west of Gwespyr and in beds that appear to lie just below the Gwespyr Sandstone east of Holywell the genus *Gastrioceras* is well represented. *Pterinopecten*, *Posidoniella* and *Lingula* are also found.

Parallel changes of lithological character are further found by Mr. Wedd to affect the higher portion of the Lower Coal Measures. The Gwespyr Sandstone of Gwespyr in the north-west of the district constitutes a group of thick massive fine-grained sandstones which make a good building-stone. The main sandstone-beds are thick and only parted by sandy shale at wide intervals. The whole group here must have a thickness of 200 feet or more, and may maintain nearly as great a thickness as far as Holywell; though there the individual sandstone-beds are probably less thick, and a greater proportion of sandy shales comes in. From Gwespyr to Mostyn the Gwespyr sandstones are the principal strata seen at the surface and are well displayed in numerous quarries as well as in the old inland cliff.

From Holywell eastward the Gwespyr Sandstone seems to diminish in thickness and to degenerate in great part into shaly micaceous sandstone and sandy shale. North-north-east of Halkin, and in the dingle east of that village, where it crops out not far above marine shales and limestones of the Holywell Shales, it has become a weak, flaky, micaceous sandstone with numerous softer beds of sandy shale. It still has a considerable thickness, though its outcrop cannot be traced continuously at the surface.

In the dingle known as Nant-felin-blwm, west of Mostyn, a marine bed with *Glyphioceras* and *Pterinopecten* occurs in shale either within or just above the Gwespyr Sandstone, according as an overlying sandstone, separated off by an appreciable thickness of shale, is or is not included in the Gwespyr group.

In the tract north of Mold and west of Northop, surveyed by Mr. Lamplugh, the Lower Coal Measures exhibit a continuation of the changes in lithological character noticed by Mr. Wedd in the tract adjoining on the north. Bands of hard gannister-like sandstone and sandy shales without fossils appear to replace the greater portion of the Holywell Shales so that the subdivision is difficult to identify, while the Gwespyr Sandstone can no longer be traced as a unit and is probably represented by a heterogeneous series of shales, more or less sandy, with occasional masses of sandstone. These changes have not been allowed for in the previous mapping, so that considerable alteration of the old map (79 SE.) will be required.

MIDDLE COAL MEASURES.

In the country north and east of Mold surveyed by Mr. Lamplugh the outcrop of the productive Coal Measures is for the most part concealed by drift. The exposed tracts are, however, more numerous than are shown on the old map, as is

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particularly the case on the southern slope of the Alyn valley between Leeswood and Pontblyddyn, where the drift is rarely thick enough to hide the Coal Measures. The upper portions of the gullies on this slope south of old Leeswood Hall reveal dark shales with marine fossils (*Pterinopecten*, *Lingula*, goniatites, &c.); and on the crest, 500 yards further east, there is an outcrop of a peculiar conglomeratic sandstone with pebbles of quartz, &c., ranging up to 2 inches in diameter. The district is so dislocated by faults that the position of these beds in the sequence cannot be fixed with any certainty until all the mining information of the neighbourhood has been collected and studied.

Mr. Wedd's work in the northern part of the Flintshire Coalfield has led him to some wide-reaching conclusions, which, if confirmed, will explain the hitherto baffling distribution of the coal-seams in this area.

The Middle Coal Measures, poorly exposed at the surface, are intersected by numerous faults the direction of which departs but little as a rule from due north and south. A comparison of numerous shaft-sections of the Denbighshire and Flintshire Coalfield from Ruabon to Hawarden and Mostyn affords strong ground for believing that the thickest and most important seam—the Main Coal as it is called in the Denbighshire and the greater part of the Flintshire Coalfield—is one continuous seam throughout, and is the Five-yard Coal of Mostyn. This seam is present under the coastal tract both south-east and north-west of the town of Flint, and apparently the same coal is worked at Neston, on the opposite or Cheshire side of the Dee estuary. But in the immediate neighbourhood of Flint the Main Coal is everywhere missing, together with all the higher workable coals, and also in places one or more important seams below the Main Coal. Instead of the measures containing these seams, we find at Flint a thick group of barren strata, for the most part red. Yet at Bagillt, barely three miles north-west of Flint, a shaft of the Bettisfield Colliery proves that not only is the Main Coal present, with the complete sequence of coal-bearing measures below it, but also 350 feet of Middle Coal Measures, including three or four minor seams, above the Main Coal.

In passing from Bagillt towards Flint, an interruption of the normal sequence is first found at Coleshill little more than a mile and a half distant. There the Main Coal and the two seams next below it, the Three-yard and Brassy Coals, are absent, and the position of one or both of the latter two coals is occupied by a small thickness of red measures. At the New Flint or Dee-side Colliery the Three-yard Coal is the highest seam present in the western shaft, where it is succeeded by about 300 feet of barren red measures, while in the eastern shaft, little more than 200 yards distant, the Brassy—the next lower seam—is overlain by 500 feet of similar barren measures, and the Three-yard Coal is shown in plans of the colliery to end abruptly against red rock between the two shafts. A similar state of things is found in other shafts at Flint; and at the Bryncoch Colliery, nearly a mile south of the town, the Middle Measures containing small unidentified seams below the horizon of the Main Coal are overlain by about 230 feet of barren red measures.

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It thus becomes clear that in the neighbourhood of Flint an important part of the Coal Measures, including the Main Coal and neighbouring seams, has been removed, and that the place of these missing measures is occupied by barren red strata that pass unconformably on to the lower beds of the Middle Coal Measures. The unconformable junction is not, however, anywhere seen at the surface; but the barren red measures are well exposed, as described below.

UPPER COAL MEASURES.

The Upper Coal Measures have not hitherto been recognised as occurring in Flintshire, except beneath the head of the Dee estuary where they were reached in a deep boring and identified by Dr. Strahan.[1]

Mr. Wedd, however, finds that the barren measures above described as lying unconformably on the Middle Coal Measures in the neighbourhood of Flint belong to this division. These beds consist of alternations of felspathic hard massive and softer thin-bedded and micaceous sandstones of various shades of purple, red and brown; with purple mottled marls and red shales; and a minor proportion of grey shales, partly stained red and containing red-stained ironstone nodules. One bed of grey shale includes two little coal-seams varying up to 6 inches and 1 ft. in thickness. A massive bed of purple sandstone, about 100 feet above the base of the series, has a thickness of fully 100 feet, and at least one band in it contains large rounded quartz-pebbles. Some beds of purple marl are crowded with grains of sphærosiderite, while others contain occasional calcareous rubbly bands and beds consisting of a calcareous sandy matrix full of pebbles or nodules of hard purple marl. The greatest ascertained thickness of these measures at Flint is 504 feet in one of the shafts of the New Flint or Dee-side Colliery, and they occupy a continuous area of more than a square mile, which includes nearly the whole town of Flint. This tract is limited on the east by a north-south fault, which brings up the productive Middle Measures.

Half a mile east of Flint a thick massive purple sandstone of the same red series forms a second outcrop of small extent on the foreshore, but its relationship to lower measures is not seen.

A third area of these red barren measures is brought in by a fault at Rock-cliff Hall, two miles east-south-east of Flint. Purple mottled marls of considerable thickness, containing a few feet of greenish-white sandstone and a calcareous conglomerate, are faulted on the west against grey shales of the Middle Coal Measures, underlying a massive yellow sandstone. Beyond these purple marls, on their south-east side and apparently dipping under them, is a thick mass of felspathic ochreous brown and purple sandstone, which weathers to a crimson clay-soil; and again beyond it and apparently lower in the sequence, another tract of purple marl comes in, which seems to terminate against Middle Coal Measures with a faulted junction.

[1] 'Geology of Flint, Mold and Ruthin' Supplement (*Mem. Geol. Surv.*), 1898, p. 5.

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These three outcrops of red measures extend for a distance of four miles along the coast of Flintshire, while the site of the boring in which, as above mentioned, the division was previously recognised, lies little more than four miles still further east. In another boring about a mile south of this, at Sandycroft, similar red measures are recorded in an earlier Survey Memoir,[1] though classed with the underlying Middle Coal Measures.

Mr. Wedd points out that the total thickness of the measures known to be present above the Main Coal in Flintshire, including the red beds above the supposed unconformity, is itself nearly sufficient to bring in the Upper Coal Measures, even when no allowance is made for strata removed before the deposition of the red beds.

Although these red beds have the aspect of Upper Coal Measures, no *spirorbis*-limestones have as yet been found in them; but no great thickness is exposed at the surface. The great proportion of purple sandstone that they include causes them to bear a closer resemblance to the general type of the Keele Beds of the Midlands than to the normal type of the Etruria or Ruabon Marls.

TRIAS.

Mr. Simmons continued the mapping of the Wirral peninsula northward from Neston and Little Sutton to Thurstaston and Rockferry. This area is underlain by Triassic rocks widely covered by Glacial drift, but with a larger proportion of exposed rock than was found last year in the southern part of the peninsula. In spite of much faulting and irregularity, the formations as a whole dip northward, so that while the Bunter alone is present in the southern part of the area examined, outliers of Keuper set in at Heswall Hill and Storeton Hill, and this formation becomes predominant in the northern portion of the peninsula. The observed dips, however, do not usually correspond with this general structure, but are governed by the faults which have sliced up the rocks into strips running approximately north-to-south. Owing to the lack of permanently distinctive characters in the subdivisions of the Bunter, the course of these faults through the formation is often difficult to follow; but when the Keuper also is implicated, the effects of the faulting are readily recognizable. The three subdivisions of the Bunter distinguished by Prof. E. Hull, viz., Lower Mottled Sandstone; Pebble Beds; and Upper Mottled Sandstone—are all present in the area, and have been mapped separately, but with some changes in the boundary-lines shown on the old one-inch map. The late G. H. Morton suggested a further division of the Pebble Beds into a lower sandstone with numerous pebbles and an upper sandstone with few or no pebbles. This division has been found to hold good in a general way, but to be impracticable for mapping purposes, from the vagueness of the horizon at which the change occurs. In isolated exposures the distinction between the sandstones of the 'Pebble Beds' when devoid of pebbles and

[1] 'Geology of Flint, Mold and Ruthin' (*Mem. Geol. Surv.*), 1890, Appendix I, p. 217.

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those of the 'Mottled Sandstones' above and below them also often remains questionable, as their discrimination has, in many cases, to depend mainly upon the coarser grain of the 'Pebble Beds.' Some of the sections reveal interstratification of coarser and finer sandstones, thus increasing the difficulty of defining the subdivisions.

Though usually softer and redder than the Pebble Beds, the Upper Mottled Sandstone is frequently indurated into a hard siliceous rock in the neighbourhood of faults and joints. These indurated veins give rise to surface-features, in the form of low ridges, which are particularly well-defined on Heswall Hill.

The Keuper formation is subdivided into:—Basement Beds, consisting mainly of massive pale sandstones with a conglomeratic base, Waterstones, and Red Marls. The Marls and Waterstones lie mainly to the northward of the area surveyed and further reference to them may be deferred for the present. The Basement Beds are best exposed at Storeton Hill, where the pale massive sandstones are extensively quarried, and contain the celebrated 'foot-print bed,' covered with reptilian tracks, ripple-marks and sun-cracks. The Keuper of this locality forms a narrow strip brought down by north-to-south faults against the Bunter on both sides. The basal conglomerate of the Keuper is best exposed on Heswall Hill and around Mount Pleasant near Prenton; it is a persistent and readily traceable bed, generally forming a distinct feature. The coarse firm sandstones of the Basement Beds at Heswall and Irbymill Hill are overlain by a variable series of softer and finer sandy deposits, up to 50 feet in thickness, closely resembling the Frodsham Beds of the country east of Chester and approximating in type to the upper part of the Bunter.

GLACIAL.

In the portions of the Flintshire Coalfield surveyed by Mr. Wedd, Mr. Lamplugh and Mr. King, and in the part of the Wirral peninsula surveyed by Mr. Simmons, the accumulation of Glacial deposits is so heavy that the areas in which the solid rocks are exposed at the surface are greatly subordinate to those in which these rocks are hidden by drift. In both districts the most prevalent deposit is a red boulder-clay, which in its composition bears evidence of having been brought in by the ice from the sea-basin. Where unweathered, this red boulder-clay, in the inland as well as in the coast-exposures, was generally found to contain fragments of marine shells, along with boulders of rocks of distant northward origin. Stratified deposits of sand and gravel occur sporadically in association with the boulder-clay throughout the area examined.

In the Wirral peninsula, the tract surveyed by Mr. Simmons included the well-known cliff-section of Dawpool, south of West Kirby, which is continuous for three miles, with a maximum height of 60-70 feet, entirely in Glacial deposits, and constitutes the best exposure of drifts in this part of England. In this section the boulder-clay is roughly divided into an upper and lower portion by the intervention of a partly-stratified middle

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belt of variable composition, including stony loam and clay, patches of gravel, and impersistent lenticular beds of sand. This tripartite division has been supposed to be applicable to the drifts of the whole region, but even in the Dawpool section it is very inconstant.

On the Flintshire side of the estuary, Mr. Wedd found that the profile of the Carboniferous rocks beneath the drift points to the existence of an older coast-line, presumably pre-glacial, which was in places bordered by cliffs, now partly degraded and buried under drift. Borings on the margin of the estuary indicate, moreover, the presence of a drift-filled pre-glacial channel with a depth of at least 200 feet below O.D. The tributary valleys are likewise still in many places deeply filled with drift, as is shown by a boring in the valley of Swinchiard Brook, about a mile south of Flint, where the base of the drift was found at a depth of 132 feet, or only 8 feet above O.D.

Mr. Wedd noticed that, among the shell-fragments of the red boulder-clay and its associated gravels, the most abundant are representative of the species *Cardium edule* and *Tellina balthica*, which are also the most abundant shells of the ancient beaches and present shore of the estuary, and that, with the exception of *Donax vittatus* which has been very rarely found in the drifts but is plentiful in the recent beaches, the shell-fragments mostly belong to species that are still common on the coast. He considers, therefore, that the marine material of the drift was derived principally from the bed of the pre-glacial estuary.

Below the red boulder-clay in the Flint district, Mr. Wedd found in some places a small thickness of grey boulder-clay formed from the local rocks, and at one spot, about a mile south of Bagillt, this grey clay also contained a few shell-fragments.

On the slopes rising from the Flintshire side of the estuary the Glacial sands and gravels are arranged in irregular belts which suggest to Mr. Wedd that these particular deposits were accumulated along the margin of the ice-sheet during its withdrawal from the present land-area.

The transport of local boulders indicates that the ice-movement was approximately southward over the central part of the Flintshire Coalfield, and the same direction was shown by glacial striae observed by Mr. King on a surface of hard sandstone at Pen-y-mynydd.

In the country north and east of Mold, surveyed by Mr. Lamplugh, the effect of the Glacial deposits upon the physiography of the district is remarkable, particularly in respect to the changes in the drainage-system, brought about in part by the actual glaciation and in part by the residual masses of detritus left by ice on its dissolution. The drainage in the principal valleys of the mountainous country to the westward has been comparatively little altered by the glaciation, but when the streams leave the hills to cross the drift-covered coal-field they are frequently diverted into courses which bear little or no relation to the pre-glacial channels.

Dr. Strahan, in a previous memoir ('Geology . . . of Flint, Mold and Ruthin,' 1890, pp. 131-135) drew attention to some

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anomalies in the courses of the River Alyn and its tributaries, and in the same memoir Mr. De Rance mentioned a curious valley striking northward from that of the Alyn to Nant-y-Flint. In the district recently examined, the Alyn flows south-eastward from Mold for two miles along a drift-lined pre-glacial hollow, but at Padeswood this hollow is blocked by an eskeroid mass of coarse gravel, and the river escapes southward through a newly excavated trench in the Carboniferous rocks at Pontblyddyn.

The mass of gravel blocking the old valley is pitted with a remarkably fine series of 'kettle-holes' of all sizes, from 30 to 500 or 600 yards in diameter, the smaller having the form of crater-like cups, 30 to 40 feet deep, some dry and some holding small ponds. Mr. Lamplugh remarks that nowhere in the British Islands has he seen 'kettle-structure' so well shown as in the 50-acre tract forming part of the Golf Links and its surroundings at Padeswood.

The northern side-valley entering that of the Alyn west of Mold, referred to by Mr. De Rance, presents many exceptional features. It shows evidence of having been carved out mainly by flood-waters of Glacial times, which probably in part followed pre-existing hollows, but crossed and destroyed the cols between them. The long straight valley thus formed, notches the watershed between the Alyn basin and the estuary of the Dee, its steep sides being 100-200 feet high and its flat floor about 100 yards broad in the southern portion where it has not been cut into by the present streams. Several brooks draining from the upland of Lower Carboniferous rocks on the west are intercepted by the trench and on reaching its floor have deposited broad sloping delta-fans of detritus. One of these fans, ¼ mile south of Middle Mill where the Holywell-Mold highroad crosses the valley, stretches across the trench and forms the watershed between the northward and the southward drainage, thus resembling the 'corroms' of East Lothian described by Kendall and Bailey.[1]

Three-quarters of a mile further south, another small stream, descending steeply from the west near Quarry Farm, Gwysaney, has also pushed out a delta upon the floor of the main valley, and, most curiously, by this means flows straight across the trench at right angles, escapes from it at a low place on the opposite or eastern side, and takes an independent course eastward past Northop through drift-covered ground of low relief. Here known as Northop Brook, it eventually falls into the small newly-cut ravine of Lead Brook and is diverted northward to the sea at a point 1½ miles SE. of Flint. As seen in the field, the singularity of its transverse course across the broad trench is very striking, as the surrounding features appear to render it most unlikely that any waters descending into the valley could escape laterally from it.

It is further noteworthy that the stream in question heads in a boggy hollow, north of Gwysaney, from which there is also drainage in two other directions, viz. northward and westward, through valleys that are greatly disproportionate to their present streams.

[1] 'The Glaciation of East Lothian, etc.' *Trans. Roy. Soc. Edin.*, vol. xlvi., 1908, pp. 1–31.

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In yet another place, ½ mile north of Middle Mill, there has formerly been an eastward escape of a stream from the Alyn-Flint trench. This is indicated by the presence of a valley, now dry, which has its head half-way up the steep eastern side of the trench, and continues as a deep ravine past Pen-y-glyn, ending on the coastal flat a mile east of Flint. Since that ravine was cut, the main trench has been excavated 40 or 50 feet deeper by the north-flowing waters of the Afon Conwy and other streams.

The hilly country south of the Vale of Clwyd, surveyed by Mr. Smith, has been everywhere glaciated, but the principal deposits of drift occur in the valleys. In the Bryneglwys valley the rock-floor is almost continuously hidden, and patches of boulder-clay are also found on its slopes to over 1000 feet O.D. The boulder-clay in this part of the country is composed almost entirely of local material from the slaty Lower Palaeozoic rocks, along with boulders, ranging up to 15 feet in diameter, derived from outcrops to the westward. Among these, boulders of the coarse ashes and columnar andesite from Arenig Fawr are numerous, as are also blocks of Wenlock (Pen-y-glog) grit which have been carried to the east and north-east of their outcrop. The same direction of ice-flow is indicated by the glacial striae, which have a trend averaging about E. 20° N. Occasionally the boulder-clay is heaped up into drumlins, particularly in the area around and south of Llanelidan. In the valley of the Afon-Morwynion, two miles south of Bryneglwys, mounds of this kind have impeded, for a time, the descent of the stream into the Dee valley. At Bryneglwys and a few other places, local deposits of fluvio-glacial sand and gravel were mapped.

South of the Dee in the country surveyed by Mr. Wills, the composition and distribution of the drift were similar to those of the area last mentioned, the boulder-clay occurring principally in the upper parts of the tributary valleys of the Dee and the Ceiriog and around the head-waters of the latter stream. The distribution of the boulders indicates an easterly direction of ice-movement. Near Rhos-Pengwern at about 1200 feet O.D., Mr. Wills mapped a small patch of coarse sand and slate-gravel overlain by boulder-clay, but elsewhere the high-level drift appeared all to be boulder-clay. In the valleys draining north to the Dee there is a rather sharp contrast between their expanded upper portions and their narrow and deep lower parts, but drift occurs in both, these and other features suggesting that there has probably been a rejuvenescence of the Dee at a time immediately antecedent to the Glacial period. Between Carrog and Llangollen the present river appears to be flowing at about the same level as did the pre-glacial stream.

POST-GLACIAL.

In north Flintshire, the area surveyed by Mr. Wedd included the Point of Air. This promontory is composed entirely of recent deposits, bordered on the south by bluffs which were once sea-cliffs. Mr. Wedd found that blue estuarine clay formed the basis of the promontory, this being covered in places by ridges of pebbly

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sand and shingle, representing old storm-beaches, and by dunes of blown sand. This part of the coast is now suffering some erosion and the sand-dunes have in places travelled a considerable distance inland since the current Ordnance Survey map was made.

On the Cheshire side of the estuary Mr. Simmons surveyed a broad alluvial tract north of Burton Point, consisting of salt-marsh at present overflowed by the highest tides, but gradually being built up by the accretion of silt and sand, and already covered in part by marsh-plants. Inland, near Heswall, Mr. Simmons mapped a small area of peaty sand which appears to represent wind-drift from the outcrop of Triassic Sandstone to the westward.

In the Alyn valley, Mr. Lamplugh and Mr. King mapped a wide spread of river-alluvium below Mold, which owes its deposition to the previously-mentioned dam of drift that blocks the valley at Padeswood.

In the upland country west of the Denbighshire Coalfield the areas surveyed by Mr. Smith and Mr. Wills included numerous tracts of hill-peat, with small alluvial deposits in the valleys.

2.—Warwickshire and Staffordshire District.

Mr. G. Barrow, District Geologist.
Dr. W. Gibson.
Mr. E. E. L. Dixon, B.Sc.
Mr. C. H. Cunnington, B.Sc.
Mr. T. Eastwood.
} Geologists.

The survey of the area contained in the one-inch map 154 has been completed, and the work continued southwards into the Sheets 168 and 169. Considerable information has been gained on the question of the extension of the workable coal-seams beyond the areas within which they are at present mined.

CAMBRIAN (WARWICKSHIRE).

The detailed mapping of the pre-Carboniferous rocks on the east side of the coalfield, begun by the late Mr. C. Fox-Strangways, has been continued by Mr. T. Eastwood. The beds so far examined consist of dark-blue and red shales forming the middle and lower portions of the Stockingford Shales. Sill-like intrusions of moderately basic igneous rock occur in both portions, but are more abundant in the middle. Owing to their harder and more resistant nature, these sills, which have a high dip to the west, form a series of ridges, some of which include a number of intrusions separated by thin shale-partings. Mr. J. Pringle has obtained *Agnostus* from the dark shales, and from calcareous nodules in the red shales overlying the Hyolite-limestone in the Camp Hill Quarry has collected fragments of *Callavia*.

SILURIAN.

The southern end of the Walsall inlier of Silurian rocks has been surveyed by Mr. Cunnington. Between Great Barr and Bustleholm the Wenlock Beds consist of soft green-grey shales

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containing layers of irregularly shaped limestone-nodules, frequently rich in fossils. They form a low-lying tract of land bounded on the south-west by the unconformable Coal Measures; to the south-east they are abruptly truncated by a continuation of the 'Eastern Boundary' fault which has been mapped by Mr. Cantrill in the area to the north.

CARBONIFEROUS ROCKS.

(1.)—*Warwickshire.*

The mapping of the four divisions of the Carboniferous rocks of North Warwickshire has been continued by Mr. Barrow and Mr. Eastwood. These are as follows in descending order:—

(1) Keele Beds or Upper Red Marls and Sandstones ('Permian' of the Old Series Map).
(2) The Halesowen Sandstone and Grey Marl Series, or Upper Grey Measures.
(3) Etruria Marls and Espley Rocks, or the Lower Red Marls.
(4) The Lower Grey Measures in which alone workable coal-seams occur.

(4) *The Lower Grey Measures or Productive Measures on the east side of the Coalfield.*—A complete sequence of these measures has been obtained by Mr. Eastwood, partly from surface-observations but largely from information kindly supplied by the various mine-managers. Special assistance has been given by Mr. Lindley of the Nuneaton Colliery, Mr. Phillips of the Ansley Hall, Mr. Trench of the Haunchwood and Mr. Harper of the Griff Colliery.

The relative position of the various coals that are or have been worked in the district is shown in the following table, given in descending order:—

Coal, the Four Foot.	
Measures, varying from 50 to 130 feet.	
Coal, the Two Yard	Forming one seam
Thin parting	Forming one seam
Coal, the Ryder	Forming one seam
Thin parting	Forming one seam
Coal, the Bare	Forming one seam
Measures, variable	Total 90 feet.
Coal, the Ell	Total 90 feet.
Measures, variable	Total 90 feet.
Coal, the Slate or Nine Foot.	
Measures with thin coal (Lady Coal). 90 feet.	
Coal, the Seven Feet.	
Measures, including several coal seams. 90 feet.	
Coal, the Bench.	

The Four Foot seems to have been worked so far as it lay at small depth; its working is discontinued.

Of the Two Yard, Ryder and Bare Seams the upper only is now worked; the other two were worked near the outcrop. The upper seam is known locally as the Two Yard, and the one immediately below is called the Ryder, but which of the two is the Ryder that is extensively worked to the north-west and west is not yet clear. The Two Yard varies in thickness from 5 to 6 feet; the Ryder is about the same; the Bare is between two and three feet thick. The Ell Coal is about 4 feet thick; it is

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only in occasional demand at present, but was worked to a considerable extent in some of the older pits.

The Slate Coal varies from 9 to 10½ feet in thickness and is still rather extensively worked.

The workable part of the Seven Feet Coal is from 5 to 6 feet thick. It is less worked than the Two Yard or the Slate, the workings in it being discontinued in some pits.

The Bench Coal was formerly worked near the outcrop, but it is not now mined in the deeper shafts. It varies in thickness from 11 feet with thin partings to 5 feet solid.

The seams between the Seven Feet and the Bench are only worked in association with a clay, and the coal is not sent away. The beds between the Seven Feet and the Bench have been laid open in Messrs. Stanley Bros. clay pit No. 3. Here the Bench Coal forms the steeply sloping eastern side of the pit, while the Seven Feet occupies the brow of the western side. In this excavation some unusual phenomena have been observed in connection with a 'dumb fault' or wash-out in the seam next below the Seven Feet. The dip suddenly increases for a few feet and the middle and upper parts of the seam are replaced (or washed out) by a lenticular mass of sandy shale, though the lower part is continuous. The upper part continues for a short distance on top of the shale, gradually thinning away but becoming broken up and mixed with a shale-material before ending off. The lenticle extends for about 30 feet and, where it terminates, the lower part of the coal-seam rises up sharply from beneath it. The seam does not at once regain its full thickness, but thickens and thins irregularly throughout the rest of the excavation. The overlying Seven Feet seam is not affected, but the underlying coal, immediately beneath the point where the dip suddenly increases, is sharply cut off, as though faulted down, for it is said to occur in full thickness at a lower level beneath the wash-out or shale-lenticle.

These wash-outs are a feature of the northern part of the Warwickshire Coalfield, but have not been exposed to view of recent years. They are specially abundant in the Ryder Coal and one is known to attain a width of more than a mile. Their comparative scarcity in the Seven Feet Coal may be connected with the fact that this seam has a roof of marine shale, while that of the Ryder is either estuarine or freshwater.

Little is known at present of the beds between the Bench Coal and the base of the Coal Measures. In the Stockingford area a number of small trial-pits was made not far from the uprising mass of Cambrian shales, in search of a good bed of clay. None was found nor was any workable coal met with. The junction of the Cambrian and the Coal Measures has been traced by Mr. Eastwood from Purley Park to the Midland Railway near Stockingford. North-west of Chapel End, in a cutting leading to some disused brickworks, the Coal Measures rest on the Stockingford Shales. The basal bed is here a conglomerate associated with coarse sandstone. Pebbles of vein-quartz are common, as are also angular chips of the Cambrian shale, while fragments of quartzite are occasionally met with; north-westwards pebbles become less

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abundant, until at Purley Wood the basal bed becomes a coarse sandstone with quartz-pebbles, overlain by rather fine-grained red and yellow sandstones. South-east of Chapel End neither sandstone nor conglomerate are met with, while near the railway the Coal Measure clays rest directly on a thin sheet of diorite.

In the area further north, the basal sandstones cross the road to Atherstone. They are here associated with some red clays or marls of doubtful thickness but of some importance, for similar red beds have been met with on the opposite side of the coalfield, at Wilnecote. There, in the bottom of a pit sunk to a considerable depth below the Bench Coal, a boring was made, the record of which has been kindly supplied by Mr. J. Cook, mine-manager of Messrs. Skey & Co. It penetrates the beds to a depth of nearly 400 feet below the Bench Coal, and proved that the basal portion of the series is much thicker than on the east side of the field, near the uprising Cambrian rocks. Further, at a depth of about 200 feet below the coal, red and white marls were met with, and at 260 feet a bed of coarse conglomerate 9 feet thick. The lowest beds penetrated were as follows in descending order:—

	Feet.
Red rocky marl	24
Rough conglomeratic rock	6
Red marly rock	28
Rough rock, coal-smut at base	1
White rock, penetrated to	3

The occurrence of these red marls close to the base of the Coal Measures explains part of the section obtained from a boring at Desford, some 12 miles ENE. of Atherstone. The cores were examined by Dr. Gibson,[1] who found that while the Carboniferous Limestone and Millstone Grit were of normal character, the overlying sandstones and red marls had not been recorded elsewhere. It appears now that these red beds have a wide range; they underlie the lowest workable coal-seam.

Changes in the Coal Seams.—The re-survey of the Warwickshire Coalfield, which started from the northern end, has now progressed sufficiently far south to verify the conclusion reached in the former survey by Mr. Howell and published in 1859 in the Memoir on the district. The coal-seams may be divided into two groups, in the upper of which the coals thin and deteriorate going north and in addition become much further apart, while in the lower the coals tend to thicken and improve going north and also become further apart but less markedly than in the case of the upper seams. At the north end of the field the Seven Feet, the Double and the Bench are worked but none of the upper seams.

In the belt of ground lying between Wilnecote and Kingsley the Seven Feet of the lower group and the Four Foot of the upper are both worked; in passing southwards through this belt the upper seam thickens and improves, while the lower deteriorates until at the south end, on the west side of the field, its working has locally ceased. In the Haunchwood area Mr. Eastwood's

[1] 'Summary of Progress' for 1904 (*Mem. Geol. Surv.*), 1905, p. 151.
'Leicester and South Derbyshire Coalfield' (*Mem. Geol. Surv.*), 1907, p. 347.

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account shows that the working of the lower seam is discontinuous, while higher thick seams have come on that are unrecognisable at the north end of the field; further these seams have already come close together, three forming practically one seam.

(3.) *The Etruria Marls and Espley Rocks, or Lower Red Marls.*—Mr. Eastwood finds that the Etruria Marls in the Stockingford area have a thickness of about 170 feet. The upper part usually consists of green-grey shaly marl with brown-skinned nodules of limestone, occasionally containing *Spirorbis*. Lower down the marls are of the cuboidal type and show red and grey mottling, mostly parallel to the bedding; mottling is also present but is less common along the edges of cracks or veins traversing the bedding. The breccias and conglomeratic bands to which the name of Espley Rocks is applied are irregularly distributed; often a passage can be traced from them to the normal green-grey marl. First the marl becomes harder and more sandy, passing gradually into a fine flaggy sandstone; later it changes to a pebbly grit and finally to a breccia or conglomerate. The pebbles in the Espley Rocks are mostly vein-quartz and chips of shale, both set in a marl-cement. The chips of shale closely resemble extremely weathered Stockingford Shale and it may be noted that the shale immediately under the basal Carboniferous conglomerate is broken up and forms red and green marls with numerous small flakes of shale. At Haunchwood, where a fine section is exposed, the marls on weathering often break up into small discs of shale. Mr. Eastwood's work at Stockingford thus shows that the phenomena are much the same as those observed on the opposite side of the field, at Whateley; the composition of the Etruria Marls is greatly influenced by the proximity of land-surfaces composed of Stockingford Shales.[1]

To the north-west of Stockingford, Mr. Eastwood finds that this effect is still further marked, for these Lower Red Beds change in character and are no longer recognisable as marls. In addition they become much thinner and may be locally absent altogether. At the Nuneaton Colliery they are 170 feet thick and separated from the underlying Four Foot Coal by 170 feet of grey Coal Measures. But at Ansley Hall Colliery, only 2 miles to the north-west, there are only about 100 feet of strata between the base of the Halesowen Series and that coal-seam, and the whole of the beds appear from the description of the shaft to be grey Coal Measures. This points either to the total thinning away of the Red Beds or to their having been eroded before the deposition of the Halesowen Sandstone.

As the Etruria Marls had not been recorded on the north-eastern edge of the Coalfield, a brief visit was paid to that region, and it was ascertained that strata of considerable thickness intervene between the Halesowen Series and the grey Coal Measures, but that they are as a whole unlike the normal marl, and that though here and there this material is present, the dominant constituent is decomposed Cambrian shale. In several cases there is a sudden swelling of the basal bed of the Halesowen Series accompanied by

[1] 'Summary of Progress' for 1911 (*Mem. Geol. Surv.*), 1912, p. 24.

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extensive erosion of the underlying beds. At the Tamworth Colliery, which lies about centrally in the Coalfield but towards its northern end, a brick-pit shows a considerable amount of red, chocolate, greenish and grey marl. This indicates a reversion to the normal type and suggests that the abnormal type is confined to the edges of the coalfield, and to the neighbourhood of the flanking masses of Cambrian shale. The new shaft in the middle of the field but far south of the Tamworth Colliery, confirms this view. Immediately below the Halesown Series there lies a mass of typical Etruria Marls consisting of chocolate, mauve and green strata.

(2.) *The Halesowen Series, or Upper Grey Measures.*—A considerable tract of the Halesowen Series has been mapped by Mr. Eastwood in the area about Stockingford, on the east side of the Coalfield. As usual, sandstones predominate in the lower part, the upper consisting largely of pale-grey marls. The series varies considerably in thickness; at the Haunchwood Pit it is about 350 feet, but only a mile to the east, at Whittleford pumping station, it has diminished to 170 feet, but it thickens again in the same direction as the outcrop is approached. This variation is well shown by the beds of sandstone; the one at the base of the series is fairly persistent, but while it is 60 feet thick at the Nuneaton shaft, it has diminished to 15 feet at the pumping station. This basal sandstone has been traced in a north-westerly direction from Heath End to Ridge Lane near Bentley Wood, a distance of four miles. Good sections of it occur at the Haunchwood brickpits and in the mineral railway at Arbury Road. The rock is of rather coarse structure and pale in colour but it rapidly turns brown on exposure, later becoming dirty-white and disintegrating. The higher sandstones seem to occur more as wedges, but there is always at least one present.

In the overlying pale-grey marls a limestone containing *Spirorbis* sparsely is persistently present at about 120 feet below the top of the series. It is a hard compact grey rock of variable thickness, the maximum known being three feet six inches. There can be little doubt that this is the index-limestone already described as occurring on the western side of the field. In the middle of the Halesowen Sandstone Series there appear to be lenticles or nodules of *Spirorbis*-limestone, but no persistent band.

(1.) *Keele Beds or Upper Red Measures ('Permian' of the Old Series Maps).*—On the western side of the Coalfield the mapping of the Upper Red Measures has been continued by Mr. Barrow in a southerly direction.

The marls and sandstones which constitute the series form distinct features in the landscape. At the base a group of sandstones with subordinate marls usually forms a well-marked escarpment. Above this the first mass of marl occupies a considerable area of nearly flat ground, which is followed by a second more or less continuous escarpment formed by a second group of sandstones. A second marl-flat succeeds, above which are some well-marked 'pellet-sandstones' forming a third steep slope with the Whitacre Limestone at its top.

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At a height of about 100 feet up in the series a thin bed of *Spirorbis*-limestone has been traced for a small distance and a similar bed, at apparently the same horizon, has been met with in other and distant localities. The limestone is distinguished by the fact that *Spirorbis* is more than usually common in it.

A feature of the sandstones is the occurrence, generally near their base, of pellets of marl and pale calcareous clay (possibly 'race'); these tend to occur in lines, but in some beds the marl-pellets are crowded together so as to form distinct lenticles varying in length from a few feet to several hundred yards. These 'pellet-beds' differ from the true conglomerates in that the fragments are exclusively of local origin.

At a height of about 500 feet up in the Keele Beds there occurs a dark-blue, or black, *Spirorbis*-limestone which has been described by Mr. Cantrill.[1] It attains sufficient thickness to have been worked for lime, and can be traced for a considerable distance.

The marls are all red, with the rare exceptions of streaks of pale-green material; but the tint varies. The lower marls are of a duller red than the higher beds, while a brilliant pink is developed at the horizon of the Whitacre Limestone.

Under the light of a more extended experience some rocks near Tamworth, hitherto supposed to be Keuper Sandstone, have been re-examined in company with Dr. Strahan with the result of showing that they belong to the Keele Beds. Proof was obtained by the finding of a thin *Spirorbis*-limestone, corresponding in position to the thin band described above and like it containing the characteristic fossil in some abundance. Another outcrop of what may be the same band has been found near Fazeley Bridge over the Tame on the east side of the river. It should be understood that these *Spirorbis*-limestones, where too thin to have been worked, are most difficult to trace; they can be found only in ploughed fields where the ground is absolutely clear of drift or wash.

The proving that the supposed Keuper Sandstone at Tamworth is really of Keele age has greatly assisted in explaining the structure of the country and the underground extension of the coals; it has also made it possible to trace accurately the position of the great faults limiting the present coal-workings. The further details of this area about Tamworth are reserved for the Memoir on the district.

On the east side of the Coalfield about Stockingford, Mr. Eastwood finds good exposures in the mineral railway near Poplar Tree Farm. The sandstones are red-brown in colour and often very calcareous, 'pellet-beds' being common. The marls frequently contain small nodules of limestone, but *Spirorbis* has not yet been detected though thin bands of very fine-grained calcareous sandstone are common in the thicker marls and are at times so calcareous that they are called limestones. The line

[1] Spirorbis Limestone in the Permian of the South Staffordshire and Warwickshire Coalfields. *Geol. Mag.*, 1909, p. 451.

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of demarcation between the Upper Red Series and the underlying Halesowen Series is seldom well-marked; in many places there seems to be a perfect passage between them.

(2.)—*South Staffordshire.*

The survey of the South Staffordshire Coalfield has been continued by Dr. Gibson in the districts of Bilston, Wednesbury, and West Bromwich.

The outcrops of the Carboniferous rocks are mostly concealed under waste-heaps and buildings. The Superficial Deposits are also thick and widely spread, so that the work has to a large extent consisted in the collection and tabulation of the information obtained from mining-plans.

Between Toll End and Oldbury some large clay-pits show that the Etruria Marls or Lower Red Marls occupy considerable areas, but are broken by several large faults which introduce narrow belts of the Productive Coal Measures. The red measures consist chiefly of red, purple and mottled clays with irregular bands of the characteristic coarse green grits (Espley rocks). A lenticular band of grey sandy shale resting on a thin shaly coal is exposed in Hamblet's marl-pit near West Bromwich. This lenticular bed of grey material lying towards the middle of the red clays, has yielded many fragments of plants which usually are particularly rare in this part of the Coal Measure sequence.

In South Staffordshire the mapping of the Keele Beds has been continued by Mr. Cunnington in the neighbourhood of Great Barr and Hamstead. The lowest beds come to the surface between Hill Farm and Peartree Farm along the eastern margin of the Boundary Fault, and form a small inlier at Hamstead. They consist of red marls with beds of soft red sandstone and occasional 'pellet-beds,' but contain no conglomerates. At Hill Farm there is also an outcrop of *Spirorbis*-limestone, no doubt the same band as that met with in the Hamstead shaft at a height of 330 feet above the base of the Keele Beds.

At a height of 900 feet above the base of the Keele Beds, the sandstones are locally conglomeratic; they contain abundant pebbles of foreign origin, among which red and yellow cherts are abundant and characteristic. The lowest beds are well exposed in the large quarries at Hamstead, where they consist of red marls and sandstones, showing a lenticular structure common in all the sandstones of the upper red beds, as well as in the greyer beds below. It was at the Hamstead Quarry that Mr. Hardaker found fossil footprints which he considers identical with some occurring in the German Rothliegende.[1] For this reason, it has been suggested that a divisional line should be drawn by which the lower portion with 'pellet-beds' would be classified as Keele beds, while the upper part with conglomerates would remain as Permian. It may be possible to trace such a line over much of

[1] *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 639.

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the area, but so far no evidence of any unconformity at this horizon has been found. Some distance above the Hamstead sandstones, Mr. Cunnington has found the conglomerate containing a large proportion of pebbles of Carboniferous Limestone mentioned by Jukes.[1] The bed is markedly lenticular and thickens and thins rapidly. It is best seen in the Vicarage garden at Great Barr, and this outcrop has been traced for about a mile. The band is substantially identical in composition with the well-known Arley conglomerate of the Warwickshire Coalfield, which also occurs high up in these red beds well above the Whitacre Limestone already referred to.

HOPWAS AND SUTTON BRECCIA BEDS.

The Hopwas Conglomerate or Breccia has now been traced over a large area and its relationships ascertained. It lies at the base of the Bunter Conglomerate, but may be nearly 100 feet thick at one point, yet cut completely through by this conglomerate not far off. It is not affected by the pre-Triassic faulting and earth-movements; in fact the discordance between it and the Carboniferous is substantially as great as that between the Bunter and the Carboniferous.

Continuing its mapping westward to Sutton Coldfield, Mr. Cunnington has found a considerable development of hard sandstone with beds of coarse breccia, intervening between the Keele Beds and the Bunter Conglomerate. In general type these breccias resemble those of Hopwas, but differ from them in the comparative scarcity of limestone-pebbles, the commonest constituents being angular pieces of greyish coarse quartzite, decomposed igneous rock and fossiliferous Silurian sandstone. At Four Oaks the series must be at least 100 feet thick and between this locality and the Bunter escarpment at Barr Beacon it has always been found wherever the Bunter Conglomerate has been penetrated. Over this area it is distinctly unconformable to the underlying Keele Beds, while there has also evidently been a considerable amount of local erosion before the deposition of the Bunter Pebble Beds, for south of Great Barr Hall it has been entirely cut out.

During the visit paid to the north-eastern margin of the Coalfield (in Sheet 155) referred to on p. 25, the Hopwas Breccia was found by Mr. Barrow to be characteristically developed, but near the Anker River to be resting on a part of the Keele Series, 1000 feet lower than that on which it rests at Hopwas. Moreover in a road-section east of Polesworth Station it rests on beds 200 feet above the base of the Keele Beds, while an outlier of breccia close by lies not more than 100 feet above that base. The overstep is due to the fact that the dip in the Keele Beds is much higher than that of the Breccias. The breccia on the other hand closely follows the Bunter.

TRIAS.

The mapping of the broad belt of Triassic rocks lying between the two coalfields has been continued in a southerly direction.

[1] 'South Staffs. Coalfield' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 13.

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Mr. Cunnington has confirmed the view that the Bunter Pebble Beds between Sutton Coldfield and Barr Beacon, though of wide extent, do not reach any great thickness. In several cases the underlying Breccia Beds and even portions of the Keele Series reach the surface.

A notable feature is the decrease in coarseness of the Bunter Conglomerate, and its partial replacement by sandstone, as Birmingham is approached. At Aston the whole of this division has been proved by borings to be only 300 feet thick, and to be composed of pebbly sandstones into which the overlying Upper Mottled Sandstones pass down so insensibly that it is difficult to draw any line between them.

A considerable area of Keuper Marl has been mapped by Mr. Cunnington and Mr. Eastwood. The former has ascertained that these marls were penetrated to a depth of 700 feet without reaching their base at Moxhull New Hall. A little south of this locality he has found a thin bed of coarse greenish, white-weathering sandstone, apparently the equivalent of the 'Arden Sandstone' of the country further south.

On the east side of the Warwickshire Coalfield, near Wash Lane Bridge between Stockingford and Nuneaton, Mr. Eastwood has found a small outlier of Keuper Sandstone not previously known.

GLACIAL DEPOSITS.

The Western Drift.—The mapping of the Glacial Deposits has been continued by Dr. Gibson in the area to the south of Willenhall and Walsall. They vary much in thickness, attaining 90 feet at Hall End, but dwindling locally to a few feet, or more rarely disappearing altogether, as at Toll End. While at West Bromwich, Wednesbury and Bilston they repose on higher ground formed of Carboniferous rocks, in the Tame valley they are lying in a valley or hollow cut in these rocks. Even here they are often still so thick as to suggest that they once formed an almost continuous platform, and that the present ground-surface is the result of deep erosion.

As in the area to the north, the drifts can be divided into two parts, the upper of which is unbedded, while the lower is usually well-bedded.

The unbedded drift is of the usually gravelly nature, the pebbles being mostly derived from the Bunter, but there is generally some clay in the matrix and at times it is present in sufficient quantity to form a gravelly clay. Drift of this type, though not always the thickest, is much the most widely spread. The bedded drift is of more local occurrence and is composed of bedded sands (often fine) and coarse gravels. These are well displayed in the large and deep pits at Hall Green, where the coarse sands and gravels, from 10 to 20 feet thick, rest on the more finely bedded sands, from 20 to 30 feet thick. The latter are here often so compacted as to resemble Bunter Sandstone.

These bedded drifts appear to have blocked the original eastern course of the Tame Valley and to have diverted the river to its present northerly course toward Bescot Junction.

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They extend eastward to Swan Village, but to the south seem to end abruptly against a steeply sloping bank of Carboniferous rocks; they are here overlapped by the unbedded drift which spreads onto the Carboniferous rocks.

In the district of Moxley the drifts fill up an old valley as noted by Jukes.[1] More recent information has been obtained by Dr. Gibson, proving the extreme narrowness and the steepness of the sides of the hollow. At the north end of Moxley village an extensive sand-pit has been opened close to the east side of the Birmingham Canal. Here 20 feet of red silty clay are seen resting on a bed of coarse gravel built up of wedges and varying from 10 to 12 feet in thickness. At the base of the gravels are some 30 feet of bedded sand the upper surface of which is eroded or channelled. The actual base of the sands cannot be seen but it is known from the workings in the Thick Coal below that the pit must nearly reach it. The floor is strewed with large boulders of Coal Measure sandstone and of the local igneous rocks, both showing glacial markings. Notwithstanding the depth of the drift, yet at a distance of only 300 yards to the east of the pit the Coal Measures actually crop out. The surface of the ground is approximately level. At the west side of the canal a shaft has been sunk to a depth of over 30 feet entirely in Coal Measure clays; it is situated close to the edge of an old sand-pit, which, though now partially filled in, still shows a thickness of about 30 feet of drift. Thus this old valley is not merely very narrow, but its sides are steep, in spite of their being formed largely of soft clays. Its course northward from Moxley is obscured by spoil-heaps, but some 400 yards to the south its position is again shown by the thickness of drift exposed in the Monway sand-pit. Here the coarse gravels rest on some 30 feet of bedded sands containing layers of coal-detritus in which numerous angular and rounded fragments of black shale and coal are abundant. On the eastern side of the excavation the sands rest on a dark-blue clay containing blocks of black shale and coal, together with occasional rounded pebbles of quartzite, but apparently devoid of erratics of distant origin.

Mr. Cunnington also has mapped considerable masses of these bedded sands and gravels between Sutton Coldfield and Birmingham. They vary much in composition, in some cases consisting mainly of sand, while in others gravel predominates. A common feature in this area is the red colour of the sand which is so pronounced that, as noted by Dr. Gibson, the material when compacted closely resembles Bunter Sandstone. Sections frequently show contortion of the bedding. The surface of the ground formed of the bedded drifts differs in shape from that formed of the unbedded drift.

While mapping the unbedded drift toward Erdington, Mr. Cunnington found that the normal gravelly material is apparently absent and that a red clay, containing but few pebbles, but in which erratics have been found, rests on the bedded drifts.

The Eastern Drift.—The only new point of importance with regard to the Eastern Drift is the discovery of what may be called

[1] 'South Staffs. Coalfield' (*Mem. Geol. Surv.*) ed. 2, 1859, p. 207.

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a Lower Boulder Clay. It consists of a tough red clay packed with stones, many larger than a man's fist. The stones are mostly sharply angular, and though quartzite is abundant fragments of Charnian rocks are sufficiently common to leave no doubt as to the eastern origin of the deposit. Similar patches have now been found at several localities, and at Shuttington Hill this clay clearly underlies the bedded sands containing abundant flints.

The former extension of this clay is proved by the numbers of fairly large angular stones scattered over the ploughed fields. Their distribution is limited along a line locally trending north and south, and so sharply as to show that the deposit ended off with singular abruptness.

3.—London and SE. District.

Mr. Clement Reid, F.R.S., District Geologist.
Dr. R. L. Sherlock.
Mr. Henry Dewey.
Mr. C. N. Bromehead, B.A.
Mr. R. W. Pocock, B.Sc.
} Geologists.

During 1912 the field-work was carried eastward into London. The Aylesbury one-inch map is now complete, and the North and South London maps are well advanced.

The district on which the staff has been engaged is occupied by Chalk and Tertiary deposits, overlain by extensive sheets of Drift. Being so near London it is well known to geologists, but much that is of importance both scientifically and economically may be expected to result from the systematic mapping and correlation of the different parts. It is difficult however to explain new points before the detailed maps are available. The geology around London is far from simple. There is still much uncertainty as to what happened in Pleistocene times in this border-land between the glaciated and non-glaciated regions. The courses of the streams have evidently been altered at various points; but it is not yet clearly understood by what agency, though the evidence is increasing that tongues of ice advanced beyond the main ice-sheet and entered the Thames Valley. What part these tongues, with their extensive sheets and fans of fluvio-glacial gravel, played in diverting the rivers is still doubtful. It will be necessary to study the lower reaches of the Thames and its Essex banks before we can speculate why the Thames makes such peculiar curves above London.

One of the greatest difficulties met with has been to understand and differentiate the various drift-deposits which occur near the southern limit of the ice-sheet, *i.e.*, on the southward slope towards the Thames. Boulder-clay, Clay-with-flints, Brickearth and Fluvio-glacial Gravel seem to be more or less interchangeable terms in this northern part of the area. To add to the confusion Eocene material occurs in reconstructed masses which are often most difficult to distinguish from Eocene-in-place, and Chalk may pass imperceptibly into Chalk-rubble.

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These masses of Eocene material need a word, as their occurrence suggests the active agency of ice further south and at higher levels than is ordinarily thought. They form irregular sheets on the Chalk, often resting on zones not far above the Chalk Rock, and usually they underlie the Clay-with-flints. But unlike the Eocene outliers in non-glaciated areas, which form conspicuous mounds or hills visible from afar, these Chiltern outliers form no features and are only recognisable through the brickyards which are opened in them. They usually show also too much disturbance to allow of their being regarded as Eocene deposits in place. Their mode of occurrence suggests rather that this area of Chalk downs was once dotted over with mounds or hills of Eocene, such as are seen in the non-glaciated regions south of the Thames; and that these mounds were rolled out or smeared along, with complete obliteration of the features, into extensive sheets of more or less reconstructed Eocene material.

In the last 'Summary' the discovery by Mr. Noble of an exceptionally rich fauna in the Chalk Rock near Marlow was noted. These highly fossiliferous patches appear to be quite local and of small extent, for though we have since examined many miles of Chalk Rock outcrop few others have been found. One occurs not far from Little Gaddesden, where Mr. Reid came across some highly nodular Chalk Rock with lumps of phosphate and a profusion of sponges and gasteropods. Here a highly varied fauna is again associated with the presence of abundance of hard nodules, which seem to have formed stony patches on a sea-bottom elsewhere consisting mainly of soft mud. This may be the explanation of the striking concentration on such spots of the crawling animals, such as gasteropods and cephalopods, and also of the exceptional abundance and variety of many organisms which require a solid base on which to fix themselves. The areas between these gravelly patches were too soft for most gasteropods, and were therefore inhabited only by sedentary animals. The same phenomenon is noticeable in a far higher zone, for in the Trimingham chalk also the gasteropods are confined to a hard nodular layer two or three inches thick, and have not yet been found in other parts of the deposit.

The uncertainty as to the true limits of the undisturbed Eocene strata makes it difficult to speak with confidence as to the extent of the outliers, and it is almost as difficult to decide on what exact horizon in the Chalk they may rest. Dr. Sherlock and Mr. Pocock find, however, that northward between Abbots Langley and Luton Hoo, the Reading Beds become more variable and tend to overlap on to lower zones. Almost the whole of the Upper Chalk appears to be overlapped in that direction, so that the base of the Eocene comes to rest on strata only a short distance above the Chalk Rock.

The variability of the Reading Beds is particularly noticeable at Cowcroft (called also Tyler's Hill), where the two sides of the small outlier show widely different sections. On the west there is a considerable development of sand in the lower part, but at the brickyard on the east side of the red clay is said to rest directly on the Chalk. A disused pit in the wood shows clearly

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the junction of the Reading Beds with the Chalk. It is a horizontal plane, but the Chalk has been bored into by mollusca and the cavities are now filled with glauconitic sand. Fragments of the shells may still be found at the bottom of the borings.

The London Clay calls for no special remark, but the Claygate Beds (transition-deposits into the Bagshot Sands) prove to be of considerable thickness and of importance economically. In Richmond Park and round Wimbledon Common, Mr. Bromehead has separated them from the underlying London Clay. The only clear section is in Coombe Wood, where the beds exposed are precisely similar to those of the type-locality; there are, however, a number of ancient pits, now almost entirely obscured, where the loams of this division were formerly dug for brickmaking. Above the Claygate Beds there are occasional small patches of Bagshot Sands; but as these are in every case covered by Plateau Gravel, their exact limits are unknown. On the western edge of Wimbledon Common there are one or more of these little outliers, which owe their presence to the slight westerly dip at that locality; but the same cause is responsible for their small extent. When the Plateau Gravels were laid down as a level sheet their eastern margin lay directly on London Clay, but to the west they overlapped successively the whole thickness of the Claygate Beds and a considerable thickness of Bagshot Sands. The drainage of the gravels and sands flowed down the dip-slope of the impervious beds and escaped in the form of strong springs into the valley of the Beverley. These springs washed out the sand, with the result that the gravels were gradually let down, so that we now find them descending nearly 100 feet below their normal level on the west, whereas in the east that level is maintained and their margin is sharp. That this sagging is due to the gradual removal of the underlying sands rather than to ordinary hill-creep is shown by the undisturbed current-bedding visible in exposures of the gravels even at their lowest margins. The sands still remaining may form patches of considerable extent, but they are only visible in a single pit on the flanks of Copse Hill.

The Glacial and Fluvio-Glacial deposits examined during the past season are complicated and puzzling. So far the examination by Dr. Sherlock and Mr. Pocock of the interesting area between King's Langley and St. Albans shows not only that we are dealing with the marginal deposits of an ice-sheet, but that we have to do with a mingling of material from two sources. The Clay-with-flint and associated gravel here give place to a gravel which is connected with the chalky boulder-clay.

Extensive excavations on the Associated Portland Cement Company's works at and around Swanscombe in Kent gave an opportunity not to be neglected for examining the succession of the Palaeolithic deposits in the Thames Valley. Thanks to the facilities offered by the Company, and to the interest taken in the work by their Manager (Mr. G. Butchard), the Geological Survey and the British Museum were able jointly to undertake the detailed examination of perfectly clear vertical sections. Mr. H. Dewey on behalf of the Geological Survey and Mr. Reginald Smith on behalf of the British Museum were entrusted with this

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work, and the results, as far as the geology is concerned, are given in an Appendix to this Summary (p. 82). It is interesting to find that Britain yields the sequence of implements already known in the Somme Valley, and that Palaeolithic implements of different types can now be used as zone-fossils. Unfortunately the associated animals and plants found in the Swanscombe excavations were too few to help much in the correlation.

(B.)—SCOTLAND.

The field-work in the Highlands was arranged in two districts as follows:—

(1) West Highland District under Mr. C. T. Clough, M.A.
(2) North and Central Highland District under Mr. L. W. Hinxman, B.A.

The Coal-field revision was also carried on in two districts.

(3) The Kilmarnock District (Ayrshire) under Mr. C. T. Clough, M.A.
(4) Carluke, East Kilbride and Douglas District (Lanarkshire) under Mr. L. W. Hinxman, B.A.

1.—West Highland District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. G. W. Lee, D.Sc.
Mr. J. E. Richey, B.A.I.
Mr. G. V. Wilson, B.Sc.
} Geologists.

The area surveyed lies entirely in the Island of Mull, and is all included in the one-inch map 44 with the exception of a small marginal strip in the next map to the north (52).

LIAS.

Dr. G. W. Lee inspected the Carsaig Mesozoic rocks that had previously been surveyed by Mr. Lightfoot, and he also examined the area of Mesozoic rocks which form the promontory and base of the cliffs south-west of Port Ohirnie, two miles and a half south of Loch Buie. There is at Port Ohirnie an imposing section, comprising the sequence from the top of the Gryphaea Limestone to the top of the Middle Lias. The Lower Lias is some 400 ft. thick, but is not divisible into palaeontological zones, owing to the imperfect state of the fossils. Further details as to the palaeontology of the Lias will be found on page 74.

We can now state that search for a possible representative of the Raasay Ironstone would be fruitless in the part of Mull included in Sheet 44. The sections in the Loch Don district, at Port na Muice Duibhe and at Carsaig show the absence of ironstone of economic value. It is, however, of interest to note that conditions suitable to the formation of ironstone occurred during

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a brief period at Port Donain and at Port na Muice Duibhe, as shown by the presence of a layer of small clay-ironstone nodules and of a thin ferruginous band, less than one inch thick, in the Upper Lias of these two localities respectively.

CRETACEOUS.

The Cenomanian strata make conspicuous features in the Carsaig district, where they were first discovered and described by Professor Judd. The lithological characters are there very much as in Morvern, beginning with a highly glauconitic phase and getting calcareous upwards. The steep stream forming a series of waterfalls above Carsaig House displays the following section:—

	Ft.
White sandstone (Tertiary)	15
Glauconitic sandstone containing layers of a thin-shelled lamellibranch crushed beyond recognition (*Remanié* Cenomanian)	15
Glauconitic sandstone with lenticular lumps of limestone	10
Glauconitic sandstone with fucoid markings and lumps of limestone	5
Massive white sandstone with obscure casts of lamellibranchs	8
Sill	6
Highly glauconitic sandstone	2
Middle Lias white sandstone	200

Fossils are in a better state of preservation along the strike in a westward direction, and consist mainly of *Exogyra conica* (J. Sow.).

On the west side of the bay the lithological characters are somewhat different. Above Aird Ghlas the succession is:—

	Ft.	In.
Calcareous sandstone with lenticles of unfossiliferous limestone	5	—
Massive pebbly sandstone, slightly glauconitic, with layer of *Exogyrae* near top	10	—
Dark thin-bedded glauconitic sandstone with *Exogyrae*	7	-
Soft black shale with nodules of glauconitic sandstone		4
Obscurely bedded sandstone, highly glauconitic ...	2	6
Middle Lias white sandstone.		

TERTIARY ROCKS.

Carsaig.—The results of an examination of the Carsaig section by Dr. G. W. Lee support the view expressed by J. Starkie Gardner that the Carsaig "Chalk" is *remanié* and should be ascribed to the base of the Tertiary[1] rather than to the Upper Cretaceous, which was Professor Judd's view.[2] This interpretation rests on the fact that the masses of chalk observed do not form bedded layers, but are dispersed without order in a sandstone matrix. The best exposure is in the stream above Feorlin cottage,

[1] 'On the Leaf-beds and Gravels of Ardtun, Carsaig, &c. in Mull.' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 284.

[2] 'The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands.' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, p. 730.

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50 yards above the left affluent, which gives the following section:—

	Ft.
Basalt lavas	—
Purple mudstone	3
Layer of chalk fragments in black sandy matrix ...	2
Massive white pebbly sandstone with red staining ...	6
Lenticular band of white flints	2
Massive white pebbly sandstone with red staining ...	14
Cenomanian.	

The lateral variation of these beds is rapid and considerable. In the affluent 50 yards below, the highest bed seen is a white sandstone. It is underlain by a 2-foot layer of chalk fragments resting on a sill which caps the massive sandstone referred to above. Eastwards, the number of chalk fragments diminishes: at the waterfall Eas Meanain there is no distinct layer of bedded chalk fragments, but angular fragments are irregularly scattered throughout the mass of the white sandstone. Still further east, at Eas na Dubhaich, above Carsaig House, no chalk occurs in the white sandstone, which is here a little glauconitic. It merges downwards into glauconitic sandstone with crushed lamellibranchs, which may possibly be *remanié* Cenomanian.

The sandstone with chalk can be traced on the western side of Carsaig Bay, as far as the waterfall at the Nuns' Pass quarries, where it dies out.

In the gully above Aird Ghlas the following section shows a type of sedimentation different from that on the east side of the bay:—

	Ft.
Basalt lavas	—
Soft shaly sandstone with fragments of flints	1
Greenish sandstone with flints and lumps of chalk ...	2
Purple mudstone	1
Greenish sandstone with a few lumps of chalk and flints	5
Gap	1
Cenomanian.	

South of Loch Scridain.—The survey of the ground south of Abhuinn a' Ghlinne and west of the Beach River, as far as included in Sheet 44, has been completed by Mr. Anderson. It consists entirely of olivine-basalt lavas, with some intercalations of sediment, and intrusions of pitchstone, tholeiite and olivine-free dolerite, like those referred to by him in last year's Summary (p. 34). The sediments include thin bands of dark shale and thin coals (*see* p. 49). The lavas vary greatly in thickness. One which measures only 10 ft. is probably the terminal portion of a flow which is elsewhere better developed. At Tràigh Cadh' an Easa' the whole lower half of the sea-cliff is at one place formed by a single member of the series, with bent and twisted columns beneath the usual slaggy top, the two together amounting to not less than 180 ft.

A system of north or north-west normal faults is well developed in this as in some other parts of Mull, and is later than the tholeiite intrusions. On theoretical grounds it seems likely that it was developed more or less contemporaneously with the north-west dykes.

Ben More to Loch Buie.—From a point near the head of Loch Scridain Mr. Anderson surveyed eastwards to the Allt Teanga

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Brìdeig, and Mr. Wilson southwards to Glenbyre, on Loch Buie. These adjoining areas present many features in common. The country rock is a basic type of andesite lava, partly porphyritic in character as described by Mr. Clough in last year's "Summary of Progress" (p. 34), but also largely non-porphyritic. A feature of all the series has been the production of secondary epidote, possibly as a result of the subsequent heating due to minor intrusions. The epidote may replace the felspar, and it also occurs in great abundance filling the steam cavities, where it has been found associated with minute dodecahedra of honey-coloured garnet. These andesites, as suggested by Mr. Clough, overlie the basaltic lavas of the plateau country, with which at their base they alternate, and constitute the group of "pale lavas" of Ben More described by Sir Archibald Geikie.[1] Perhaps the best section is the precipitous east face of A'Chioch where the group is seen to have a thickness of at least 1,000 ft. They are faulted by a group of north-and-south faults, and are thrown into gentle undulations, which have no obvious relation to the peripheral type of folding so evident in other parts of Mull.

A remarkable rock is described by Mr. Wilson which from the evidence so far gathered appears most likely to be a lava. This has a wide exposure on Beinn na Croise, and contains basic felspar phenocrysts, often quite fresh and clear, up to ten inches in length and four inches in breadth.

The next phase of igneous activity in this district consisted in an intrusion of granophyre, and this was followed by a period of minor intrusions which show diversity both in type and mode of occurrence. An attempt has been made to arrange these chronologically.

(1.) Perhaps the earliest of all are certain north-north-east dolerite dykes, which are present in the ground referred to but are much more frequent in Mr. Clough's area to the east of the Allt Teanga Brìdeig (p. 45), where they are cut through by dolerite inclined sheets, probably of class (4).

(2.) Another very early type includes certain porphyritic acid inclined sheets, with conspicuous felspar, and in some cases a characteristic pink weathering. The most prominent example occurs in Mr. Wilson's area a little to the south of Rossal, where it forms a sheet with a gentle inclination to the north, and is cut by certain thin inclined sheets of dolerite (4). These rocks will be referred to for convenience as belonging to the Rossal type.

(3.) There are in this area a large number of subacid inclined sheets dipping mainly towards the east. Needle-shaped felspars and herring-bone skeletal growths of augite form a distinguishing feature of nearly all this class. Frequently these subacid intrusions make composite inclined sheets along with the dolerites of class 4, and in these cases there is often evidence that the former are the older, a conclusion borne out by the fact that when occurring by themselves they are found by Mr. Wilson to be sometimes cut by sheets of dolerite (*see* Fig. 1).

[1] 'The Ancient Volcanoes of Great Britain,' vol. ii, 1897, p. 213.

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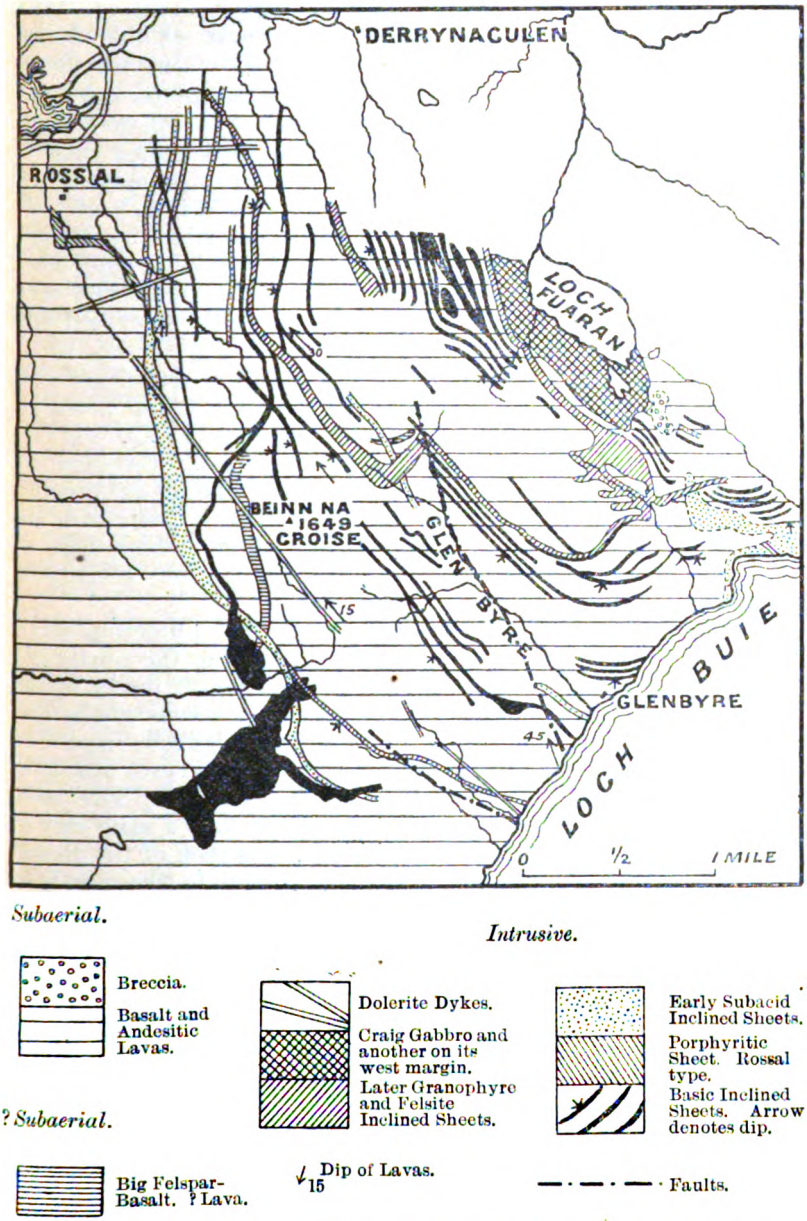

FIG. 1.—SKETCH MAP OF AREA BETWEEN ROSSAL AND LOCH BUIE.

(4.) Perhaps the most abundant of all the minor intrusions are inclined sheets of olivine-dolerite, with or without porphyritic felspar. These have a general dip of from 30° to 60°, and strike approximately parallel to the last group.

(5.) Another set of inclined sheets have been found in Mr. Wilson's area, and have the same general direction as the two foregoing. These consist of granophyre and felsite, and have been shown by him to cut certain of the dolerites (*see* Fig. 1).

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The inclined sheets of groups (3), (4) and (5) maintain their easterly dip from near A'Chioch to south of Rossal, but then swing round until on the shores of Loch Buie they dip north.

The above classification must be understood to be only provisional. Thus there is no direct evidence as to whether (1) or (2) is older, and only the similarity of habit indicates that (3) should be put immediately before (4). Again there may be two periods of dolerite inclined sheets even in Mr. Wilson's ground, apart from the later set to be afterwards described by Messrs. Clough and Anderson. These last, with the gabbro and other intrusions which preceded and followed them, form the next chapter in the history of events and are partially described subsequently under a separate heading.

Very late among the series of intrusions are a set of east-and-west dolerite dykes, which usually, with an exception noted by Mr. Clough in last year's Summary (p. 35), cut (1), (3) and (4), in the ground under description. This is probably the same set as are found by Mr. Clough to cut the Corra-bheinn gabbro and the set of inclined sheets that follow it. These in their turn are followed by the system of north-westerly dykes which here as in most parts of Mull form the last phase of igneous activity of which there is any record.

Scattered over both the districts surveyed are numerous small patches of breccia like those described further to the north and east by Mr. Bailey. These contain, in addition to pieces of the surrounding lavas, numerous fragments of micaceous gneiss and siliceous granulite, and often of a subacid igneous rock not very unlike the sheets of group 3. In one or two cases cracks in the lavas seem to be filled in with the breccia. The most westerly patch noted by Mr. Wilson is about half a mile east of Rossal, and contains fragments of an intrusive rock of the Rossal type exposed about 100 yds. away. A patch to the north of Ardvergnish has been found by Mr. Anderson to interrupt another sheet of the Rossal type, of which it contains fragments. On the other hand the breccia is cut by most of the inclined sheets of dolerite.

Loch Bà District.—In the summer of 1911 Mr. Wright returned unofficially to Mull and spent a month investigating certain points in connection with his former work that seemed to require further study. No account of this work was given in the "Summary of Progress" for that year, as it was then hoped to carry it further in 1912. This having proved impossible it is now proposed to give a brief summary of the results.

The vertical wall which forms the south-eastern boundary of the Glencannel granophyre has been carefully examined and is found not to be of the nature of an ordinary igneous junction. It is everywhere accompanied by a remarkable crush-breccia, containing fragments both of the granophyre itself and of the adjoining lava-like rock which forms a wall between the granophyre and the encircling belt of granite and hybrid rock. The inner vertical margin of the hybrid belt is brecciated in a similar manner, and this outer crush-breccia can also be seen on the south-west side of the Glencannel granophyre in the River

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Clachaig. It is probable that both crush-breccias occur right round the periphery of the granophyre. We have thus the peculiar relation of one plutonic mass encircling another and separated from it by a wall of fine-grained lava-like rock which is crushed on both sides as if faulted against the plutonic rocks. If it is a question here of two circular faults it ought to be possible to trace these faults in the lavas and agglomerates which form the roof of the plutonic masses. This, however, has not yet been effected.

Microscopic examination having shown that the rocks of the Gaodhail inclined-sheet belt are highly albitised and otherwise altered, it became necessary to enquire if they could have been earlier than any of the plutonic masses. A few of these inclined sheets cut the Glencannel granophyre but the Beinn a' Ghràig granophyre is quite free from them. This relation, interpreted otherwise in the "Summary of Progress" for 1910, p. 37, was now found to be probably due to the last mentioned granophyre being later than the inclined sheets; for a re-examination of the lava cappings on the roof of this mass showed that they contained a certain number of inclined sheets, so highly altered as to be with difficulty separable from the lavas. The evidence obtained in 1911 was, however, hardly sufficient to inspire complete confidence, but the matter has been placed beyond question by Mr. Richey's investigation of the Beinn a' Ghràig, Beinn nan Gabhar and Beinn Fhada cappings. If the inclined sheets on the north-west side are at all comparable in number or bulk with those round the remaining parts of the periphery of the Glencannel granophyre then any idea of a correlation between the post-granophyre motion along the fault[1] and the expansion due to the intrusion of the inclined sheets must be abandoned. It is clear also that the epoch of minor intrusions is not so distinctly later than that of the plutonic intrusions as had been formerly supposed.

The unconformable breccia described by Mr. Bailey in the south and east of Mull has now been proved to occur also on the summit of Beinn na Duatharach, where it contains abundant fragments of the adjoining gabbro masses. The agglomeratic rocks of Bìth-bheinn and of the plateau north-west of Creag Dhubh, and also those in the headwaters of the Gaodhail River may also belong in part to the period during which this breccia was formed.

Among minor points may be mentioned the separation of several types of rhyolitic lavas on the summit of Bìth-bheinn and elsewhere, the discovery of a mass of Jurassic grit and limestone east of Gruline, and the correction of an error in the former mapping, which showed the rocks of the Gaodhail plutonic belt in the head waters of the Glencannel River as hybrids, whereas they are almost pure granophyre.

Scarisdale and Beinn Fhada.—The mapping of the outer granophyres of Knock and Beinn a' Ghràig has been completed by Mr. Richey. It is found west of Beinn a' Ghràig that the latter

[1] 'Summary of Progress' for 1910 (*Mem. Geol. Surv.*), 1911, p. 37.

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granophyre is almost free from minor intrusions, while the neighbouring rocks are extensively cut by sheets, dykes and sills.

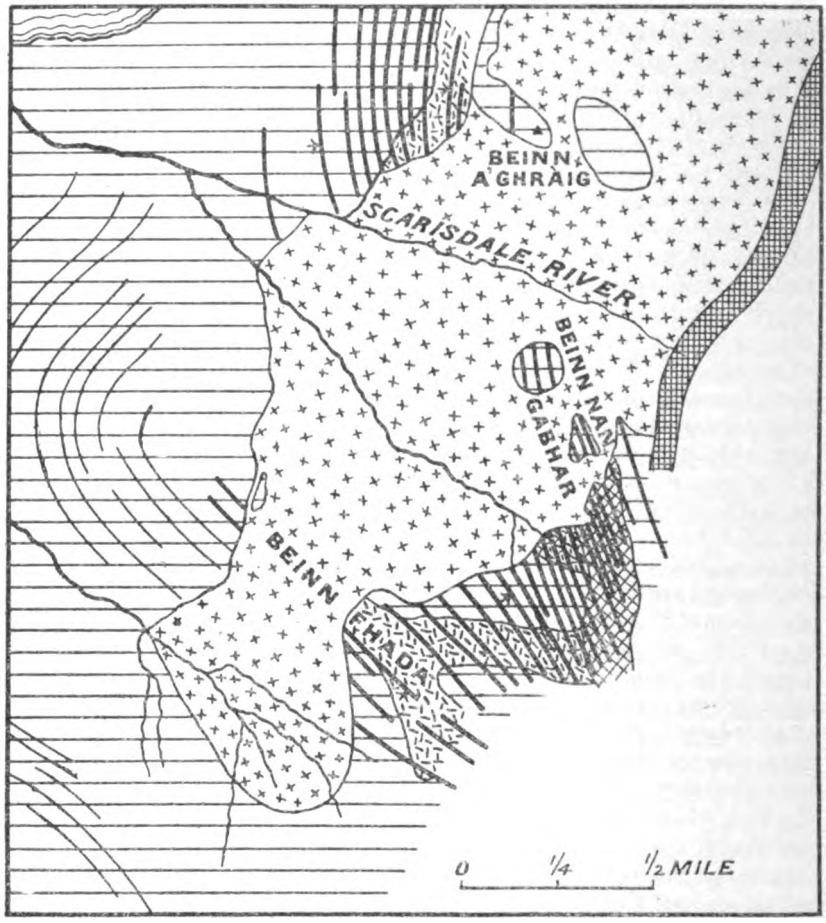

FIG. 2.—MAP OF BEINN A' GHRÀIG AND BEINN FHADA.

A belt of inclined sheets, continuing that described by Mr. Wright,[1] crosses the south-east summit of Beinn Fhada (*see* map, Fig. 2). It is then interrupted for a space by the Beinn a' Ghràig granophyre, but is represented in the lava cappings of Beinn nan Gabhar and again in the Knock felsite and granophyre and basaltic lavas.

[1] *Ibid.*, p. 35.

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The inclined sheets in Beinn Fhada are locally much veined by granophyre, and many cases have been noticed of sheets cut off by the granophyre mass itself. Further, on Beinn a' Ghràig felsites that are the marginal equivalent of the granophyre make great veins crossing the lava cappings in the same direction as the inclined sheets, and sometimes splitting them. The Beinn a' Ghràig granophyre is therefore manifestly later than the inclined sheets. On the other hand, the portion of the Knock granophyre which has been examined this year must be earlier, since it is freely cut by the inclined sheets.

A few small masses of felsite and granophyre, similarly cut by the inclined sheets, have been distinguished on Beinn Fhada; they include rocks of various types and may be capable of further subdivision. A gabbro which is older than the inclined sheets has also been mapped on Beinn Fhada.

West end of Glen More.—The great mass of gabbro which occurs north-east of Derrynaculen, and was partially described in last year's Summary (pp. 34, 35), was further examined by Mr. Clough. It was found to extend eastward at least as far as Craig, and will in this description be named after that place. Some inclined sheets have been found cutting it, but in most parts such are rare compared to those just outside. In last year's account this discrepancy was noticed, and the view was favoured, following Prof. Judd,[1] that the gabbro and the inclined basic sheets are of much the same age and represent different parts of one great intrusion. As a result of this year's work it seems probable, however, that many of the inclined sheets are earlier than the adjoining gabbro mass,[2] and are cut off by it. For a breadth of 20 yds. off the main edge of the gabbro about a mile south-east of Derrynaculen a considerable mass of rather fine-grained basic rock is intricately mixed and veined with gabbro, and to a less extent with granophyre. Near the edge and for 50 yds. north-west of it no chilled margins were noticed within the fine-grained rocks, but at a distance of 60 or 70 yds. a few were noticed, and still further away such margins became more distinctly and frequently observed. It is therefore thought probable that an alteration effected by the gabbro has largely obscured the evidence of earlier chilling, and that the basic fine-grained rocks next the gabbro in this locality represent for the most part an earlier set of composite inclined sheets. In the same locality there are, however, a few basic inclined sheets with porphyritic felspar which are chilled at and go through the gabbro. These later sheets are much less affected by irregular joints or cracks than the earlier ones and have not been injected with granophyric strings. The Craig gabbro extends southwards beyond Loch Fuaran and Mr. Wilson has obtained evidence that

[1] 'The Secondary Rocks of Scotland. Second Paper. On the Ancient Volcanoes of the Highlands and the Relation of their Products to the Mesozoic Strata.' *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 243, and plate xxii.

[2] Some of the inclined sheets are themselves entitled to the name of gabbro, but they are generally distinguishable from the Craig gabbro, and to avoid complexity in the present description the term gabbro is purposely withheld from them.

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there also it is later than a series of inclined sheets, though it is cut by other later intrusions, some of which, on the western margin, contain hypersthene.

A great mass of gabbro that is very similar in character to that of Craig, though Mr. Clough supposes it is, at all events in part, of somewhat later age, is well exposed on the southern and western slopes of Corra-bheinn, on the north side of Glen More. Most of the rocks south and west of this Corra-bheinn gabbro consist of andesitic lava or of Derrynaculen granophyre, or of basic inclined sheets cutting these rocks and dipping steeply north-east. In some places these sheets make up about half the rock just outside the gabbro, and individual members may be 20 or 30 ft. thick, yet it is clear that nearly all these are older than the adjacent margin of the gabbro and have been cut off by it. For a distance of 100 or 200 yds. inwards from the margin the gabbro is almost entirely free from later sheets, though about two-thirds of a mile south of the top of the hill the inclined sheets outside the gabbro are numerous and thick, and strike at its margin at a considerable angle. For a breadth of 20 yds. or so along its southern and western margins the gabbro is mixed with unusually numerous irregular masses of earlier basic rock. These masses are occasionally distinctly surrounded and veined by the gabbro, but of their original character it is often difficult to be sure. About a mile south-west by south of Cruachan Dearg and in various other places we see that the inclined sheets near the gabbro are veined by numberless irregular granophyric strings, giving rise to an "injection-breccia," and that these strings are also cut off by the gabbro.

It has been stated already that the Corra-bheinn gabbro for 100 or 200 yds. inward from its southern and western margins is practically free from later inclined sheets. Further inwards such sheets begin to appear, at first sparsely, but afterwards more abundantly and in thicker belts, until at the summit of Corra-bheinn they form more than half the rock and make up composite sheets 30 or 40 yds. wide. Even here they have not reached their full development, for on Cruachan Dearg there is evidence for a thickness of at least 1,000 ft. of inclined sheets with only here and there a thin intercalated wedge of the earlier gabbro still happily preserved. Where the rock just south-west of the cairn is quite bare we can never pass a greater thickness of rock than 8 or 9 ft. without coming to a chilled margin, but it is possible that many of these margins belong to thin sheets which have split thicker ones. These Cruachan Dearg sheets are divisible into various types, one of which is strikingly variolitic and has not yet been detected in the adjoining localities.

The inclined sheets intruding into the Corra-bheinn gabbro some distance within its southern and western margins usually weather in brown slabs and make nicks in the gabbro crags. They may provisionally be called quartz-albite-dolerites: specimens from some of them possess a specific gravity above 2·9. On the other hand most of the inclined sheets outside and earlier than the gabbro make rather black crags, and many are thicker and coarser in grain than the adjacent later sheets: they more often

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also contain large felspars closely packed together. Most of them appear to be olivine-dolerites, and one about half a mile south of the Corra-bheinn cairn contains enough olivine to justify the title of allivalite.

Some of the later sheets of the brown-weathering slabby type are also occasionally found outside the Corra-bheinn gabbro, where they cut through and make nicks in earlier sheets. It has been noticed in various places, as already indicated, that the earlier sheets are frequently injected by granophyric strings, but the brown-weathering later sheets never appear to be so.

The Corra-bheinn gabbro and many of the inclined sheets which cut it are themselves cut by considerable masses of rather coarse-grained later rock which are almost free from inclined sheets, being traversed by a few only, which, however, dip much the same as the bulk of the sheets in the adjacent portions of the Corra-bheinn gabbro. One of these later masses is well seen in the high valley south-west of Coir' a' Mhàim, and may provisionally be called the Coir' a' Mhàim dolerite. Somewhat further north-east is another, at Coir' an t-Sailein, which is of more variable character: in many parts it closely resembles the Coir' a' Mhàim rock, but in others is much more acid and makes an approach to granophyre.

A tongue of coarse dolerite and gabbro forms the Creag Mhic Fhionnlaidh, and runs west along the south side of the Clachaig valley, finally crossing the stream. Mr. Anderson states that this tongue does not appear to be cut by the earlier set of inclined sheets, but a part of it is cut by a set of east-and-west sheets, inclined to the north, which are a continuation, with a slightly altered direction, of the later set of inclined sheets which cut the Corra-bheinn gabbro. These east-and-west sheets are also found a short distance to the south of Creag Mhic Fhionnlaidh, where their strike is at right angles to that of the earlier system.

On the south side of the Corra-bheinn gabbro Mr. Clough found a considerable number of north-north-east or north-and-south dykes, mostly composed of dolerite, which are earlier than the adjoining inclined sheets. They nearly all incline steeply eastwards, and are of special interest because by their help it is possible to see that the inclined sheets which cut them are in a number of cases accompanied by faults, even though the sheets show no indication of crushing in themselves. These faults, so far as yet recognised in the locality referred to, are always reversed, and the displacement occasionally reaches 20 or 30 ft. in amount.

The Corra-bheinn gabbro is crossed by many thin streaks and some thick bands, as much as 10 or 12 yds. broad, of thready or else very compact greenish crush-rock. By the help of earlier acid strings, or occasionally of earlier inclined sheets (cutting the gabbro) it is seen that some of the streaks and thin bands are accompanied with small displacements, some of which are normal while others are reversed. The displacements accompanying the broader bands of crush-rock have not yet been ascertained. It is not unusual to see inclined sheets which are later than these crush-rocks, though, as already indicated, other sheets are earlier.

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Loch Buie District.—Dr. G. W. Lee found that the lower half of the southern slope of Ben Buie consists of granophyric breccia cut by a large number of inclined sheets of dolerite and of a subacid rock with acicular augite. Flows of basalt lavas are of rare occurrence. Beinn Bheag and the flat top and northern slope of Ben Buie consist of a large mass of gabbro cut by numerous inclined sheets. Most of these belong to a hard fine-grained dolerite which weathers into angular fragments with a brown surface. At the contact of some of the sheets the gabbro is altered to a green compact rock bearing a strong resemblance to euphotide. Other, less frequent intrusions, are of granophyric type. The gabbro contains also irregular included patches of finer texture, which may represent old dolerite intrusions.

South-east part of Mull.—Mr. Bailey has continued his investigation of the great Tertiary breccia, which, with minor intercalations of rhyolite lavas, forms so conspicuous a feature in the geology of south-eastern Mull (*see* Plate). No certainty has as yet been reached in regard to the mode of formation of this breccia, but the following furnishes a *résumé* of the results so far obtained. The breccia consists for the most part of blunted blocks and fragments of gneiss, granophyre, gabbro, basalt and sandstone, the last local and derived from Mesozoic sediments; along with these there is often much rhyolitic debris for part of which a truly volcanic origin may readily be admitted. The doubtful point is whether the non-rhyolitic material of the breccia has been mainly derived through explosion or erosion.

The principal outcrop of the breccia lies in a syncline east of Dùn da Ghaoithe, the course of which is indicated by the outcrops of certain porphyritic basalts among the surrounding lavas. From a consideration of the mapping it appears tolerably certain that the breccia in this outcrop forms part of an overlying cover, folded with the lavas and approximately conformable to them.

South-west of the syncline just mentioned lies the Coire Bearnach anticline, along the axis of which are exposed all the rocks, except rhyolite, recognised in the breccia. Not only are all these rocks exposed at the surface at the present time, but it is clear that they were already exposed during the period of breccia-formation. This deduction follows from the fact that a very considerable outcrop of the breccia extends across the anticlinal region, where it comes in contact, in sections which admit of careful scrutiny, with disintegrating granophyre, gabbro, basalt, sandstone and gneiss. This transgressive outcrop of breccia may be interpreted, either as the infilling of a complex volcanic neck, or as a remnant of the material which once choked a valley carved by erosion along the anticlinal axis. The latter view receives considerable support from the manner in which the breccia outcrop, north-east from Sgùrr Dearg, coincides with a narrow ridge separating two broad exposures of gneiss in the valleys on either side. It is very difficult, however, to determine the relation of the breccia to the older rocks since the junction is intensely irregular, just as one would expect according to either interpretation.

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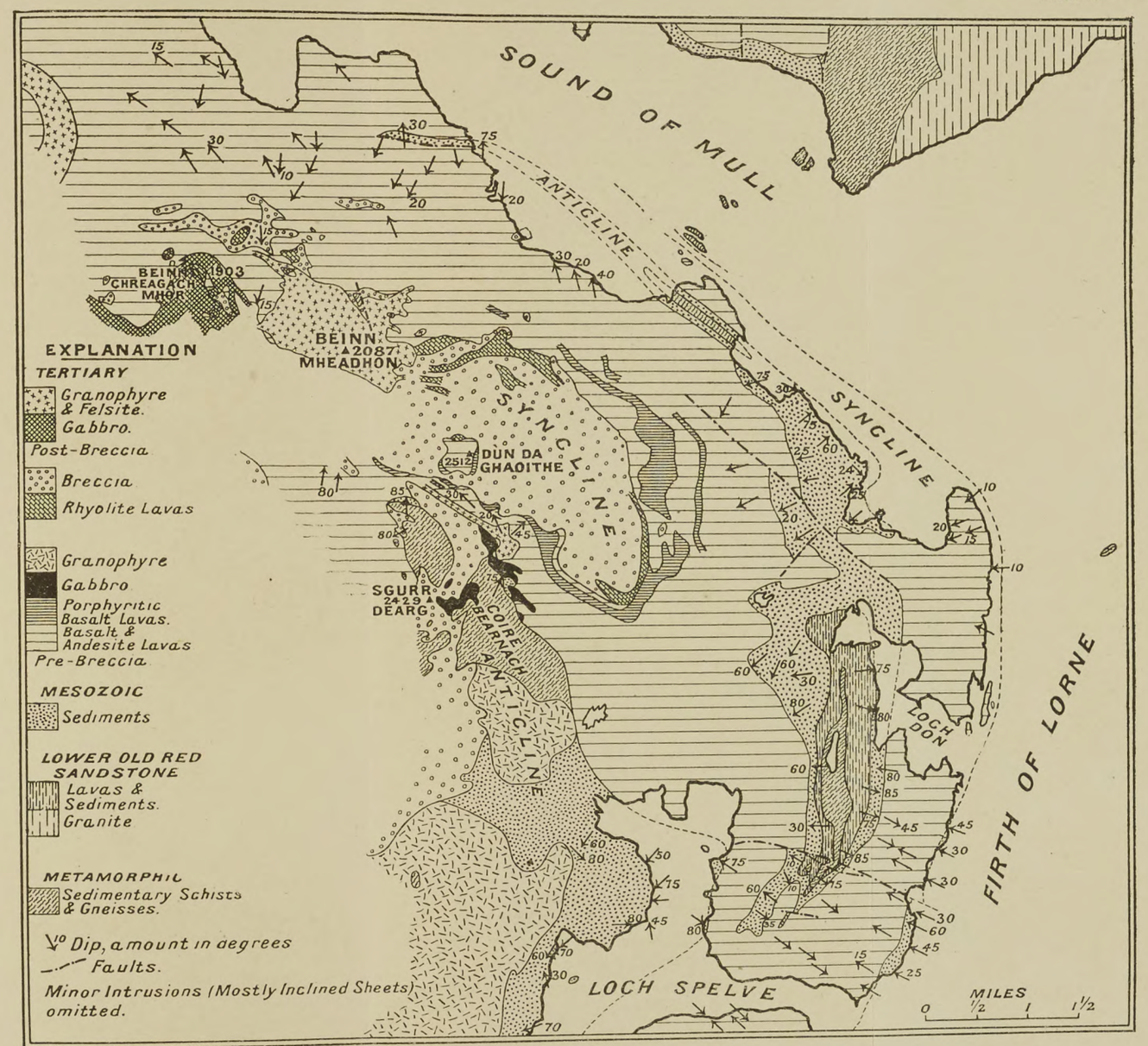

SKETCH MAP OF SOUTH-EAST MULL.

To face p. 46.

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A point which tells somewhat in favour of the explosive origin of the breccia has been raised in conversation by Mr. Lamplugh. The breccia of the synclinal region contains gneiss fragments even in its basal portions, whereas if the infilling of the syncline were due to the erosion of the neighbouring anticline one might reasonably expect a basal breccia composed entirely of basaltic and andesitic debris. This is a consideration which must be borne in mind although, of course, it is merely suggestive; the accumulation of the breccia in broad spreads would almost certainly be dependent upon climatic conditions, and might not be initiated until erosion had already cut deep into the anticlinal ridge.

In passing it may be explained that the pre-breccia granophyre shown in the Plate has been grouped as Tertiary on account of its petrological affinities. The pre-breccia gabbro has been more definitely dated, since, at one locality, it shows clear intrusive contacts with the Tertiary basalt lavas.

Of intrusions later than the breccia, we may note numberless inclined sheets, both basic and acid, of which only one, however, is shown on the accompanying map; this one is a particularly thick inclined sheet of coarse gabbro, well exposed in Beinn Chreagach Mhòr. Of earlier date than these inclined sheets, but still clearly intrusive into the breccia, is a large laccolitic intrusion of fluxion-felsite constituting Beinn Mheadhon. It is of irregular form, and its sides are sometimes very steep, but the base is often inclined at quite gentle angles. It is particularly interesting to find so large a mass as this illustrating the phenomena of composite intrusions, the importance of which Mr. Harker has emphasised. At many points along both the lower and the upper margin of the felsite a foot or two of basic rock occurs, and between the two is a xenolithic breccia in which fragments of the basic rock are enveloped in a matrix of hybrid constitution.

PLEISTOCENE AND RECENT.

Corra-bheinn and Cruachan Dearg.—Mr. Clough finds evidence from roches moutonnées and glacial striae that ice at a certain period moved in a south-western direction over the pass at Coir' a'Mhàim, between Beinn a'Mheadhoin and Corra-bheinn, and also over the next pass to the west, near Coir' an t-Sailein, between Corra-bheinn and Cruachan Dearg. The height of the first pass lies a little below the 1,250 foot contour, but that of the second is about 1,750 ft. The pass at Mam Clachaig, nearly a mile west of Cruachan Dearg, was crossed by ice moving in a southerly direction: the height of this pass is about 1,088 ft.

Loch Buie District.—The area mapped by Dr. G. W. Lee east of Allt Mhic Slamhaich, does not contain any large areas of glacial drift, but the work of ice is shown by numerous erratic blocks, moutonné rocks and ice striae. North of Loch Fuaran the striae indicate a southerly ice-flow, while in Gleann a'Chaiginn Mhòir the flow was west of south.

Mr. Wilson states that the 100-foot raised beach is well marked near Cameron Farm, and that the 25-foot beach forms a rocky shelf with occasional patches of gravel in many places along the north-west shore of the same loch.

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ECONOMICS.

Sapphire.—A mineral find of particular interest has been made in two localities to the west of Carsaig. In the first of these (1 in Fig. 3), large xenolithic blocks of baked sandstone and shale, and possibly other rock types, are seen to be involved in an igneous matrix which is probably intrusive, and which encloses large numbers of little hexagonal plates of clear blue corundum. These may fairly be described as sapphire, but anything hitherto found has been much too minute to be of gem value. The second locality (2 in Fig. 3) is on the coast at Rudh' a'Chromain, a mile to the south-west of Carsaig. Here sapphire was observed by Mr. Tait and Mr. Wilson, who traced its origin to an irregular composite sill consisting partly of andesitic felsite and partly of trachytic granophyre or syenite. As in the previous case this intrusion is full of foreign material, and blocks of baked shale figure among the xenoliths. Sapphire occurs in the baked shale, and also in the inclosing matrix. It has the same tabular habit, but the plates are larger than those previously described, measuring sometimes half an inch across. They are, however, thin and irregular, and it is a recognised fact that sapphire with the tabular habit is seldom of commercial importance.

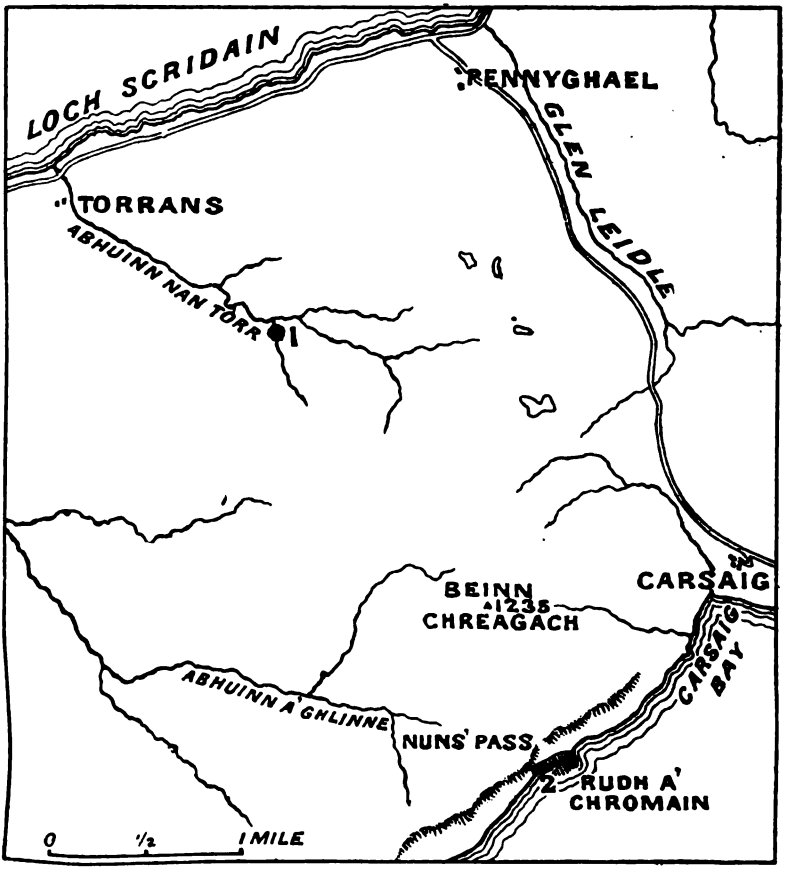

FIG. 3.—MAP TO SHOW SAPPHIRE LOCALITIES 1 AND 2.

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Coal.—It seems likely that the Cadh'Easan and Beinn an Aoinidh outcrops referred to in the "Summary of Progress" for 1910, p. 40, all belong to the same coal seam. On the west side of the valley its position can be traced from the cliff at Dearg Bhealach to near Airidh Mhic Cribhaim, where it is known to have a thickness of at least 18 ins. On the Beinn an Aoinidh side the outcrop is repeated, and it would seem to have a general thickness of from two to three feet. One adverse circumstance is the fact that thin sills of tholeiite can in two places be seen to be following the coal seam, burning it and even splitting it in two.

Magnetite.—In the Corra-bheinn gabbro on the hillside nearly half a mile west of Cruachan Dearg, Mr. Clough found various lenticular patches which appear to contain an unusually large proportion of magnetite. None of the patches observed exceed 12 ft. in length, and 3 ft. in thickness, but they have a habit of occurring near one another nearly along the same strike.

In the later fine-grained sheets of norite, &c., which occur just on the west side of the Craig gabbro west of Loch Fuaran, Mr. Wilson has detected bands about 4 ins. thick, which consist chiefly of magnetite.

2.—North and Central Highland District.

Mr. L. W. Hinxman, B.A. District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. R. G. Carruthers.
Mr. M. Macgregor, M.A., B.Sc.
Mr. C. H. Dinham, B.A. } Geologists.

Field work was carried on during the past season in East Sutherland and Ross by Messrs. Crampton, Macgregor and Dinham in the districts of Ben Armine (Sheet 108), Badenloch (Sheet 109), Loch Shin and Glen Carron (Sheet 102).

The survey of the solid geology of Sheet 109 is practically completed, but a re-examination of certain areas (mapped many years ago) with special reference to the superficial deposits, will be necessary before the map can be published according to the present scheme of colour-printing.

In Inverness-shire and Perthshire the mapping of the high and complicated ground to the west of Loch Treig was continued by Mr. Carruthers (Sheets 54 and 63), and that of the Moor of Rannoch by Mr. Hinxman (Sheet 54). In the same Sheet Mr. Macgregor completed the survey of the north side of Glen Lyon and carried his lines into the adjoining Sheet to the south (46), thereby necessitating a certain amount of revision of the latter Sheet.

East Sutherland and Ross.

Highland Metamorphic and Associated Igneous Rocks.

Dr. Crampton reports the occurrence, in the Allt Coire na Fearna, within the western limits of the Ben Armine Forest, of fine exposures of an altered peridotite, probably forming part

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of the mass of similar ultrabasic rock mapped by Mr. Macgregor at the head of Strath na Seilga.

The peridotite is in contact with gneisses of Lewisian type and granite intrusions. A large part of the mass is coarsely crystalline in structure and unaffected by dynamical movements; the marginal portions have, however, been converted into amphibolite showing marked schistosity. It is therefore certain that the intrusion of the ultrabasic material took place before the close of the movements to which are due the schistosity of the rocks in this district, while it is probable that it was prior altogether to those movements. The rocks of Lewisian type into which it was introduced may indeed have been gneisses older than the rocks of the Moine Series. It is possible that microscopic investigation may, however, throw some light on this obscure point.

The effects of granitisation on this intrusion are remarkable. The coarsely crystalline portions are often finely "netted" with felspar strings, suggesting permeation by an acid magma separating some of the crystalline constituents. The rock is also traversed by numerous irregular veins of granite and pegmatite. The foliated portions, however, sometimes show a much higher stage of acid permeation and the amphibolite passes into a coarse felspathic hornblende-biotite-gneiss of varying degrees of acidity. Among the more thoroughly permeated rocks is one which shows large phenocrysts of hornblende lying in all directions across the planes of foliation. Whether these planes represent fluxion-structure or are the foliation planes of the original basic rock and consequently older than the acid permeation, is uncertain; the latter is more probable in view of the high state of permeation of so much of the rock. In this case the porphyritic hornblendes must have been developed by the action of the acid material on the basic matrix.

Gneisses of Lewisian type are met with both in the Allt Coire na Fearna area and in the ground mapped by Dr. Crampton further to the north, on the east side of Strath Naver. As in the Ben Armine and Ben Griam districts, referred to in former Summaries, these rocks are closely associated with coarse, massive biotite-gneisses formed by the impregnation of pelitic schists with an acid magma.

The intimate association of the gneisses of Lewisian type in Central Sutherland with rocks of undoubted sedimentary origin leaves little doubt that a group of altered sediments formed the framework for the igneous gneisses of Lewisian type in this area.

In the Ben Armine Forest area examined by Mr. Macgregor most of the ground is covered with deep peat and rock sections are not abundant. The schists and gneisses met with are similar to those described in recent "Summaries of Progress," and include very varied petrological types. A notable fact is the abundance of sillimanite developed in the granitised pelitic schists at the head of Strath na Seilga.

The area mapped by Mr. Dinham in the basin of the Strath Cuilionach river (Sheet 102) is chiefly occupied by semi-flaggy or massive quartzo-felspathic granulites of the Moine Series. A variation to a highly siliceous, massive, quartzitic type of rock is

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found on the east side of An Cabagach, and the intercalation of highly micaceous and sometimes garnetiferous bands is a constant feature, and especially marked in the neighbourhood of Croick and Glaschoill.

A short distance to the south-west of Strath Cuilionach the eastern limb of a wide synclinal fold of garnetiferous pelitic schist enters the map from the ground to the south.[1] The northern margin of this fold has been traced westwards as far as Creag Loisgte.

The igneous rocks in this area comprise a few scattered sills of chloritic schist; a single ENE. lamprophyre dyke and several sporadic intrusions of a coarse, garnetiferous, hornblende-felspar-rock, foliated along certain planes.

A similarly sporadic occurrence of small bosses of a massive serpentinised ultra basic rock, allied to scyelite, has been observed by Mr. Dinham on the east side of Loch Shin, near Loch an Fhreiceadain. These ultrabasic masses are found in the vicinity of biotite-hornblende-gneiss, acid pegmatites and other rocks, but their mutual relations are at present obscure.

OLD RED SANDSTONE.

The Old Red Sandstone outliers to the west of Forsinard in Sheet 109 have now been completely surveyed by Dr. Crampton. The largest of these includes Ben Griam More, Ben Griam Beg and Meall a' Bhùirich, and has an area of over six square miles. Two other outliers, elongated in form from north to south, lie further to the west; one extends, with a length of three miles, from Biod Eag to a point somewhat north of Caol-loch Mòr, the other forms the summit of Beinn a' Mhadaidh and runs north and south for $1\frac{1}{2}$ miles. The rocks consist of conglomerates and mudstones, and the dip of the beds is constantly to the west. Their lithological characters have been fully described in an earlier Report.[2] A small patch of Old Red Conglomerate has been detected by Mr. Macgregor, resting on the metamorphic rocks at Loch Gaineamhach, $4\frac{1}{2}$ miles SSW. from the summit of Ben Klibreck. This is at present the most central point in Sutherland where Old Red Sandstone deposits have been observed.

PERTH AND INVERNESS-SHIRES.

Lochaber.—Mr. Carruthers continued the examination of a large tract of country east and south of Ben Nevis (Sheets 53, 54, 62 and 63). This work was undertaken in the hope of settling certain differences of opinion that had arisen with Mr. Bailey as to the structure of the area and the relationships of the Lochaber and 'Moine' Series.

The Lochaber Schists are mainly developed in Sheet 53; they comprise quartzites, mica-schists, limestones and granulites, the

[1] 'The Geology of Ben Wyvis,' &c. Expl. Sheet 93. (*Mem. Geol. Surv.*), 1912, p. 31.

[2] 'Summary of Progress' for 1909. (*Mem. Geol. Surv.*), 1910, p. 40.

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characters and tectonics of which have been fully dealt with by Mr. Bailey within the last few years.[1] Towards the south, around Loch Leven, these rocks show a comparatively low grade of metamorphism.

The schists of the Moine Series (the term is admittedly indeterminate) chiefly appear to the north and east, flanking the Lochaber Schists, in Sheets 54, 62 and 63. They are highly metamorphic crystalline mica-schists and gneisses, with acid granulites, similar to rocks described under the name of the Moine Series in the "Summary of Progress" on many occasions in the last ten years, from areas north and south of the Caledonian Canal.

According to Mr. Bailey's view, all the quartzite outcrops east and south of Ben Nevis, as far as Loch Treig and Loch Leven, belong to a single horizon (the Glen Coe Quartzite) flanked on one side by the Leven Schists, and on the other by the Eilde Flags. He believes that these strata are repeated again and again by a complex series of recumbent folds of enormous amplitude, accompanied by great 'slides' or thrust-planes of a special character, and that the folds and slides subsequently underwent further deformation, to which most of the extensive but small-scale folding now visible is due. The relationship of these rocks to the 'Moine' Schists is at the present time regarded as an open question.

Mr. Carruthers, as a result of last season's field work, has arrived at a different interpretation of this ground from that of Mr. Bailey. In his opinion there is a regularly descending succession, proceeding from Ben Nevis eastwards to Loch Treig, that embraces, not one, but five distinct bands of quartzite, separated by different beds of mica-schist and acid granulites. Most of these show constant individual characters, so far as they have been traced along their outcrops (*i.e.*, for distances of 12 to 20 miles). According to this view the 'Moine' Schists of the Loch Treig country (Sheet 54) underlie the Lochaber Schists, which pitch out entirely north and south of the loch, and are probably younger than the 'Moines.' The folding and crumpling, apparently all of one period only, are on a relatively small scale, not greater than may be observed in many other Highland areas; recumbent folds can be seen at several points, but they do not seem to be more than half-a-mile in amplitude, at the most.

The 'slides' almost invariably present phenomena of crushing and mylonisation comparable with those accompanying the thrust-planes of the North West Highlands. They are now inclined at a high angle, and are occasionally distinctly folded, having apparently been initiated before the close of the folding movements which have affected the region.

Mention should be made, however, of one good instance of an 'invisible slide.' North of Roy Bridge, the Ballachulish Limestone is brought into direct contact with the Eilde Flags by a continuation of the Fort William Slide, which here cuts out the

[1] *See* especially 'Recumbent Folds in the Schists of the Scottish Highlands.' *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, pp. 586–620, and plates xlii–xliv.

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whole of the Leven Schists besides the quartzites with their intervening beds. There are many stream sections, all showing the slide marked by obvious crush lines, which are themselves distinctly folded. But in one excellent section across the junction, 1¼ miles west of Bohuntine Hill, there is no evident disruption, but the beds are slightly reddened. The flags and limestone are certainly much drawn out, but this is often the case without any reason to suspect 'sliding.'

Glen Lyon.—During a part of the field season Mr. Macgregor was engaged in mapping the ground along the southern margin of Sheet 54. It was hoped that some definite relation would be established between the rocks of the Beinn Achallader ridge and those of Glen Lyon, but until more is known regarding the structure of the northern part of Sheet 46 it will not be possible to deal adequately with the tectonics of this belt.

The following table shows the successive rock-zones met with in passing south from Innerwick in Glen Lyon to Ben Lawers:—

1. Siliceous flags of the Moine Series.
2. Group of rocks including garnetiferous pelitic schists, thin limestones, and a remarkable band of hornblende-schist intercalated with thin siliceous ribs.
3. Pebbly quartzite.
4. Garnetiferous mica-schist with quartzose bands.
5. A calcareous and garnetiferous series, comprising highly garnetiferous muscovite-gneiss, calcareous schist, and bands of crystalline limestone repeated by folding. (Loch Tay Series).
6. Ben Lawers Phyllites (Ardrishaig Phyllites).
7. Black schist.
8. Pebbly quartzite.

The beds all dip in a southerly direction.

To the west of the large fault which crosses Glen Lyon at Bridge of Balgie a similar succession has been determined. The pebbly quartzite of Zone 3 can be traced from Creag Dubh in Sheet 46 across the Lyon at Moar Shuas to Loch Giorra, whence it is continued northwards in the quartzite belt which forms the hills of Garbh Mheall and Meall a' Phuill. Zones 4 and 5 can likewise be followed across Glen Lyon into Sheet 54 at Lochs, until they are cut off by the Sloc na Creadha fault. The same zones, repeated by folding, are probably represented by the belts of pelitic gneiss with limestone bands mapped by Mr. Hinxman on the Rannoch side of the watershed.

An interesting intrusive rock is well exposed in the Gleann Da-Eig burn, 1 mile above its junction with the river Lyon. The rock appears to be an igneous complex of basic and ultrabasic material, probably a peridotite, cut by strings and veins of a later gabbro. Much of the ultrabasic rock is now in the form of greenish actinolite and tremolite-schist.

PLEISTOCENE AND RECENT.

Rannoch and Glen Lyon.—The striæ observed on the high ground between Loch Rannoch and Glen Lyon indicate an ESE. movement of the ice obliquely across the watershed at an early

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period in the glaciation of the country. Further evidence is supplied by the occurrence of numerous boulders of the Moor of Rannoch granite along the dividing ridge up to an elevation of nearly 2,900 feet.

The later valley glaciation is chiefly expressed in the excessive over-deepening of the valley of the Lyon between Moar, above Meggernie Castle, and Roromore. The glens through which the Allt Connait, on the north side of the Lyon, and the two streams on either side of Sron nan Each, on the south, fall to the main river are striking examples of hanging valleys whose mouths lie several hundred feet above the level of the main stream.

Mr. Macgregor notes that Lochs Dhamh and Giorra, on the north side of Glen Lyon, each occupy a step in a glen which repeats all the glacial phenomena of the main valley. Loch Giorra lies 45 feet below the level of Loch Dhamh, and this fall is comparable with the rock gorges that so regularly connect the long alluvial stretches of the river Lyon, some of which probably represent drained loch-basins. A protracted halt of the Lochs Valley glacier at the present outlet of Loch Giorra is indicated by the fine moraine which crosses the valley at that point. This has now been cut through, and the course of the outflow stream, the Allt Connait, to its junction with the Lyon, 500 feet below, is entirely through rock.

Both the lochs referred to above are evidently rock-basins.

3.—Ayrshire.

Kilmarnock District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. J. E. Richey, B.A.I.
Mr. G. V. Wilson, B.Sc. } Geologists.

The area revised lies entirely in one-inch map 22. We have to thank many mining companies and proprietors for information kindly given.

CALCIFEROUS SANDSTONE SERIES AND CARBONIFEROUS LIMESTONE SERIES.

Galston and Burn Anne.—Prof. James Geikie during the original survey mapped a small outlier of undoubted Carboniferous rocks (with red mudstones of more questionable horizon at their base) lying isolated upon the Lower Old Red Sandstone volcanic rocks of Burn Anne. Mr. Bailey states that the sediments belong to the Carboniferous Limestone Series or else to the upper portion of the Calciferous Sandstone, for they include a well developed ferruginous limestone with *Productus*. This limestone is overstepped, bed by bed, in a westerly direction by a black shale, so rapidly in fact that, in a horizontal distance of 24 ft. the thickness of the limestone is reduced from 5 ft. 4 ins. to 1 ft. 2 ins. In about the same distance farther west the limestone is cut out altogether, as is also the overlying black shale, which is nowhere

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more than a few feet thick, by a calcareous grit with markedly irregular base. This local unconformity was recognised by Prof. Geikie, and has been rendered certain by digging out a continuous exposure. The Carboniferous System in this part of Ayrshire is remarkably thin, so that one may expect that it includes many such local unconformities; at present there is very little, if any, evidence to show whether the limestone unconformably overstepped in Burn Anne belongs to the Upper or the Lower Limestones of the Carboniferous Limestone Series.

Lugton District.—In Duniflat Burn three-quarters of a mile north-east of Lugton, Mr. Richey has recognised the marine band of *Productus* shale with *Lingula* shale on top that occurs in the Glasgow District above the Johnstone Clayband. A few fathoms of blaes with a sandstone in the middle separate it from a one-foot clayband ironstone that lies below it. This clayband ironstone is therefore correlated with the Johnstone Clayband.

Near Netherton, 1¼ miles north-east of Lugton, the following section is exposed in a cutting on the Caledonian Railway.

	Ft.	Ins.
Clayband ironstone (= Johnstone Clayband) ...	1	0
Blaes, about	10	0
Encrinital dark limestones and calcareous shales...	6	6
Blaes with ironstone balls	2	0
Clayband ironstone	0	7
Sandstone, 10 ins. to	1	8
Fireclay without rootlets, about	4	6
Black fakes	1	0
Encrinital dark limestone	1	6

The base of the bottom limestone is not seen, being cut out by a fault.

North of the fault, on its upthrow side, the section is as follows:—

	Ft.	Ins.
Blaes with a 4-in. clayband ironstone...	2	6
Light-coloured clay	0	2
Hard fine-grained purple limestone with an irregular upper surface...	2	0
Light-coloured shaly limestone with *Spirifer duplicicosta* Phil., about	3	6
Black limestone	1	0
Ash beds	—	

In Duniflat Burn the same beds are exposed with the exception of the 2-in. clay. At Lugton the clay[1] rests on the irregular top of the ostracod limestone[2] and penetrates down in streaks into it. The hard fine-grained limestone of Netherton and Duniflat is no doubt represented in part at least by the ostracod limestone, but the thin slices examined of the former do not contain ostracods. There is no other point of resemblance between the above section and the Lugton sequence.

At Lugton the total thickness of the limestone series from the ash beds to the top of the ostracod band is about 67 ft., while in

[1] R. Craig. *Trans. Geol. Soc. Glasgow*, vol. vi, 1882, pp. 9 and 10. S. M'Lennan. *Trans. Geol. Soc. Glasgow*, vol. ix, 1891, p. 93.

[2] 'Summary of Progress' for 1911 (*Mem. Geol. Surv.*), 1912, p. 49.

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the Netherton railway cutting there is only 6½ ft. This rapid decrease in thickness and the dissimilarity of the sequence in the two places suggest an overlap on the top of the ash beds.

In the Netherton railway cutting there are at least two limestones between the clay resting on limestone and the one-foot clayband ironstone. At Lugton the upper band only is seen, and was called the Upper Limestone in last year's Summary. But since we now see that there are at least four limestones at Lugton in the Lower Limestone Group, the terms Upper, Middle and Lower Limestone are no longer suitable.

Monkredding and Montgreenan.—Mr. Wilson finds that beds below the Highfield (Index) Limestone are exposed near Fergushill Hall and in the burn that runs past that place to join the Lugton Water. Numerous intrusive sheets of dolerite occur, and these have 'burnt' most of the coal seams and given them a columnar structure. A quarry a quarter of a mile north-west of Fergushill Hall shows various thin strips of coal and fireclay separated by considerably thicker sheets of intrusive dolerite.

The Index Limestone is well exposed on the banks of the Lugton Water near Mosside, and can be traced westwards through a long line of quarries to the west side of Crofthead. Information gathered from a number of bore journals has proved conclusively that this is the same limestone as the one exposed in the quarry a quarter of a mile west of Darmule, and that there is a strike fault with a downthrow to the north between the two outcrops.

The higher limestones of the Upper Limestone Group of the Dalry basin are only represented in the Lugton Water by two thin limestone posts, about 12 ft. apart, and both very siliceous.

MILLSTONE GRIT.

Monkredding and Montgreenan.—In the Lugton Water about half a mile west of Montgreenan the highest of the Upper Limestones is succeeded by about 20 ft. of grey faky rock with thin ironstone bands. From the evidence so far gathered it is impossible to say whether these beds should be placed in the Carboniferous Limestone Series or in the Millstone Grit. Between the top of these beds and a thin coal (below the Kilwinning Main), provisionally taken as the base of the Coal Measures, there are about 60 ft. of rock, the bottom portion of which is of volcanic character, while the upper portion consists of peculiar hard fireclays and ashy mudstones often full of minute specks and small nodules of carbonate of iron. The rocks are believed to be the local equivalents of the Millstone Grit. Mr. Wilson has traced their upper members from near Burrowland along the left bank of the Lugton Water up as far as the ridge south of Caven Mill.

COAL MEASURES.

Monkredding and Montgreenan.—The thin coal provisionally taken by Mr. Wilson as the base of the Coal Measures is exposed on the right bank of the Lugton Water about a quarter of a mile north-east of Burrowland. The rocks between it and the Kilwinning Main consist mainly of fakes and faky sandstone with a

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few thin coal seams which are very irregular. In this area the position of the Kilwinning Main is, as a rule, partly occupied by intrusive sheets of dolerite which have 'burnt' the coal. About half a mile west of Burrowland, however, these intrusions die out, and the Kilwinning Main has been worked to the crop.

About half a mile south of Outer Smithstone and two miles north-west of Kilwinning a coal about 6 ft. thick has been worked in crop pits. The seam is rather dirty, and has generally been supposed to be the Borestone Coal of the Dalry Basin, but the new evidence gathered seems rather to suggest a Coal Measure age, for the beds exposed below the coal near Smithstone are the characteristic hard fireclays and lavas which are believed to belong to the Millstone Grit.

Kilmarnock.—The Ladyha Coal is well seen in the old sandstone quarry just north-east of Dean Castle, and again in the Craufurdland Water about 330 yds. west of this castle, there being an east-and-west fault with a downthrow of more than 100 ft. to the south, between these two places. The identification of the seam is facilitated by the presence of an impure blackband ironstone containing very abundant remains of fish teeth, scales, &c., about 8 or 10 ft. above it. In the quarry the coal is about 16 ins. thick, but in the Craufurdland Water it is only 13 ins.

In the burn just south-east of Dean Castle, and also in the Fenwick Water near the foot, the beds a little below the Hurlford Main Coal are well exposed, and comprise among other things a massive bed of calcareous ironstone containing abundant *Carbonicola* and good cone-in-cone structure. This bed is also associated with parroty shales which also contain *Carbonicola*. Mr. Clough states that the ironstone and shale together form an unusually thick development of 'musselbeds,' and he thinks it very possible that they may represent 'The Musselband' which usually comes 30 ft. or so above the Airdrie Blackband Ironstone in the Lanarkshire Coalfield. If this should turn out to be the case, it will help to support Mr. J. Brown's correlation of the Splint Coal (top part of the Hurlford Main) of Kilmarnock with the Splint Seam of Lanarkshire.[1]

INTRUSIVE IGNEOUS ROCKS.

Kilwinning.—Mr. Anderson records a feature of special interest with regard to two thin west-north-west dykes, intrusive in Coal Measures strata near the Sourlie plantation. The more westerly one was met with in underground workings in the Turf Coal and in the Wee Coal immediately under, but no trace of it was found in the Ladyha Coal workings, 25 fms. below the last, nor in the Ell and Stone Coals which lie still lower. With regard to the eastern one the case was exactly similar, the dyke being found in the two upper, but not in the three lower coals. There would thus seem to be evidence of dykes dying out in depth in these two cases.

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[1] 'The Co-Relation of Ayrshire Coalfields.' *Trans. Ayrshire Colliery Managers' Association*, Kilmarnock. Read in 1906. Pp. 5-7, and Sheet of Vertical Sections.

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PLEISTOCENE AND RECENT.

Ardrossan and Kilwinning.—There is a clearly marked raised beach at about 110 ft. above sea-level, to the north of Ardrossan, in addition to the raised beach at 40 ft. which is shown on the published map. Mr. Anderson reports that the feature for the higher beach cannot be traced very far, but that north of Saltcoats nearly all the ground up to 100 ft. is covered by sand and gravel, and that even to the east of Kilwinning irregular gravel deposits overlying the boulder clay up to about this level may be of similar origin. It is possible that the gravel at 120 ft. above sea-level at Bannock, described by Mr. John Smith, may indicate the upward limit of submergence in this part of Ayrshire.[1]

The blown sand to the east of Stevenston is altering its position slightly and encroaching a little on cultivated ground to the east. A conspicuous line of sandhills forming part of Misk Knowes has shifted 200 or 300 yds. in that direction since the contour-lines were drawn in the year 1856.

Kilmarnock.—Above the level of 100 ft. or so the ground near Kilmarnock shows many parallel drums of boulder-clay striking NE. or NNE. Mr. Clough found that here and there such drums cease to be noticeable, and in their stead a low valley or flattish feature may extend nearly at right angles to the adjacent drums, and almost parallel to the contour-lines. It is suggested that such valleys or flats are later than the drums, and have been developed by the action of streams coursing along the margins of masses of ice which at one time covered the low ground to the south-west. An example of one of these apparently 'marginal' features has been traced more than a mile in a north-west direction, from the northern suburbs of Kilmarnock to Kilmaurs.

ECONOMICS.

In the Stevenston and Kilwinning area, Mr. Anderson states that the two highest workable coals in the Coal Measures—the Bowbridge and Crawford Seams—are not at present being wrought to any extent. Of the group of four coals which come next in order, the Five-Quarter, Parrot, Turf, and Wee, the Turf provides a good household coal, while the Wee Coal has in places a pavement of good fireclay, used for firebricks. The next coal in descending sequence is the Shale Coal, which has a roof of oil-shale, formerly distilled in retorts at Annicklodge and Doura. Ammonium sulphate was produced from this shale as well as oil, but the industry was stopped because of the distance the crude oil had to be taken to a refinery. The next coal (Ladyha) has, like the Wee, a good fireclay in places as its pavement. The Ell, the Stone, and the Lower Wee Coals are mostly used for steam and furnace purposes. The Kilwinning Main Coal usually contains partings, which may increase in thickness so as to make it

[1] 'The Drift or Glacial Deposits of Ayrshire.' *Trans. Geol. Soc. Glasgow*, vol. xi, supplement, 1898, p. 20.

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unworkable. The Raise Coal, which is the lowest Coal Measure seam of workable thickness, is not now being wrought.

Near Kilmarnock considerable areas in some of the coal seams have been 'burnt' and rendered useless by the intrusion of whin 'floats' (sills) and 'gaws' (dykes). It is nevertheless to be noted, Mr. Clough states, that not uncommonly a seam may still be worked even when a thin float occurs in it, the injurious effects only extending a very short distance from the intrusion.

In the above district some of the thin coals which were formerly neglected, and which even now could not be worked at a profit by themselves, are yet being worked in conjunction with the fireclays that occur immediately below or above them. Enamelled bricks, baths, sinks, &c., are extensively manufactured by various firms in the neighbourhood, the bulk of the raw material being got from adjoining pits, though it is stated that finer clays from a distance are used for the outer skin just below the enamel.

Near Monkredding House the coals below the Highfield (Index) Limestone have been worked on a small scale, and a sandstone which occurs above the limestone is now worked for building stone in two large quarries. The rock forms a massive bed some 60 ft. thick, is usually white or yellow in colour, and can be obtained in very large blocks.

Several lavas of the Millstone Grit and some intrusive sheets of dolerite in the Carboniferous Limestone Series are worked on a small scale by the local authorities for road metal. A broad north-west dolerite dyke at Barrmill is actively worked for a considerable distance along the crop and to a considerable depth.

4.—South Lanarkshire.

Calciferous Sandstone, Carboniferous Limestone, and Millstone Grit.

Larkhall and Strathavon.—The ground revised by Mr. Carruthers extends southwards from Limekilnburn to the River Avon between Strathavon and Stonehouse, and is divided into four separate areas by step faults, trending in a general south-east direction with a downthrow to the north.

The most northerly of these fault-blocks contains strata ranging from the Slatyband Ironstone down to the Calmy or Gair Limestone. The Ironstone, containing small *Lingulae*, is exposed in stream sections west and south of Darngaber Castle, and lower down a band of hard ochreous-weathering limestone, 2 feet thick, with occasional small encrinites, is taken to represent the Castlecary Limestone. The intervening strata, only 10 fathoms in thickness, must accordingly belong to the Millstone Grit. These are chiefly soft, coarse sandstones, conglomeratic at the base, where there is some evidence of an unconformity which locally cuts out the Castlecary Limestone as at Glenavon, two miles to the east.

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The fault-block immediately to the south brings up the Upper Limestone group of the Carboniferous Limestone Series. The two large fractures bounding the area are seen in the streams east of Crookedstonemuir, where the Calmy Limestone was formerly worked. The limestone with its characteristic *Edmondia* slate below is exposed at several points, the section agreeing with those at Limekilnburn.

The next fault-block to the south chiefly contains strata belonging to the Lower Limestone group, most of the Middle Coal and Ironstone group being faulted out, though its basal members can be seen NW. and NE. of Shotlinn.

Lower strata appear further south, and near Cot Castle, on the river Avon, there are sections of great interest in which the seven limestones characteristic of the Lower Limestone group on the south side of the Lanarkshire basin are all present. The sequence, however, is, like that in the Auchenheath area, greatly compressed, so that the highest—the Calderwood Cementstone or Top Hosie—lies only 10 fathoms above the basal member—the Main Limestone. The river cliffs below Cot Castle display in addition part of the underlying Calciferous Sandstone Series, including good exposures of the Pendleside horizon discovered in 1910 in Calderwood Glen, East Kilbride.[1] The limy shales have here yielded *Posidonomya becheri*, *Pterinopecten papyraceus* and plants, together with a long suite of commoner fossils, as at East Kilbride; they rest on a seam of blackband ironstone, worked to a considerable extent in past times.

Between Cot Castle and Strathaven, still lower strata have been noted. These contain another shell-bed with *P. becheri*, goniatites and other fossils, lying 15 fathoms below the Cot Castle horizon. A few fathoms lower down a seam of oil-shale was met with, approximately in the same position as the Raeburn seam of the Lothian shale-fields. Unlike the 'oil-shales' occasionally present higher up in the Carboniferous Series—which are more of the nature of 'parroty blaes'—this shale is of the true Lothian type and consequently of much interest, as marking the most westerly extension of these curious sediments yet recorded.

In the area between Larkhall and Stonehouse revised by Mr. Dinham, the gorge of the Avon Water, though not yet completely mapped, presents the following points of interest.

In the fairly continuous sequence of the Upper Limestones, exposed in the river section but unnamed during the original survey, it is now possible to identify the Calmy or Gair, the Orchard and the Lyoncross seams south-east of Patrickholm, while a faulted inlier immediately to the south shows several fathoms of strata above and below the Index Limestone. The impure, sandy nature of these limestones agrees with that found in the Auchenheath area[2] to the south-east, but is noticeably different from their normal character to the east and west.

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1 'Summary of Progress' for 1910 (*Mem. Geol. Surv.*), 1911, pp. 54, 65.

2 'Summary of Progress' for 1911 (*Mem. Geol. Surv.*), 1912, p. 43.

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The river-cliff beneath the site of Ringsdale Castle, one-sixth mile ENE. of Glenavon, gives the following section:—

	Ft.	Ins.	Fms.	Ft.	Ins.
Sandstone	6	0	1	0	0
Blaes	2	2	1	2	2
Fireclay with three thin coals	5	0	2	1	2
Free and foul COAL	1	0	2	2	2
Fireclay and blaes	3	6	2	5	8
COAL ... ... average	0	10	3	0	6
Fireclay...	0	7	3	1	1
Sandstone	5	6	4	0	7
Blaes with *Lingula* and "alum"	1	10	4	2	5
Blaes with 3-5 in. of C.B. Ironstone ...	1	4	4	3	9
Blaes	1	10	4	5	7
PARROT COAL, pyritous	0	3	4	5	10
SLATY IRONSTONE, 3–5 ins.	0	4	5	0	2
Faky blaes ... ... about	1	6	5	1	8
Sandstone post, 24 ft. at E., 8 ft. at W. end of section ... ... average	16	0	7	5	8
Line of erosion.					
Blue blaes	13	0	10	0	8
Blaes with three ribs of fossiliferous limestone	14	0	12	2	8
GAIR LIMESTONE, impure; in three beds, lowest, 1 ft. 11 ins.	3	1	12	5	9
Fossiliferous blaes	1	0	13	0	9
Limy shale, rough surface	0	6	13	1	3
Dark planty sandstone	0	9	13	2	0
Hard white "Ganister"	8	0	14	4	0

The limy shale beneath the Gair Limestone has all the peculiar lithological characters of the *Edmondia punctatella* horizon. The sandstone above the Gair, in addition to the rapid change in thickness shown in the table, has a very irregular base with ironstone nodules, and rests upon disturbed and eroded sandy fireclay and blaes.

In the original survey of this district the Millstone Grit was considered to include the strata between the top of the Gair Limestone and the bottom of the "Lower" Slatyband Ironstone —the horizon seen in the section. The limits now adopted are the Castlecary Limestone and the Crofthead Slatyband Ironstone. It is not yet possible to determine whether the slatyband of the above section is the same horizon as that of Crofthead, or a lower one, but it is at least certain that there is here visible evidence pointing to an unconformity in the Millstone Grit which may possibly have contributed to the already noticed attenuation of that formation at this locality.[1]

Similar visible evidence is afforded by a nearly inaccessible cliff-section half-a-mile down stream from that previously described. The base of apparently the same thick sandstone is here seen to transgress at least 24 feet of fireclays, with blaes and coal, resting on the blaes above the Gair Limestone, in a distance of less than 50 yards.

The absence of the Castlecary Limestone in the sections just described, and also from all the bores in the Auchenheath district further to the south in which the limestones can be identified, coupled with its presence in the Darngaber section referred to in

[1] 'Explanation of Sheet 23' (*Mem. Geol. Surv.*), 1874, p. 35.

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an earlier paragraph (p. 59), may thus be attributed to the existence of an unconformity which will possibly be found to affect a wide area.

Douglas Area.—The examination by Dr. Crampton of the Lower Limestones beneath the coals in the Glenbuck area and in the outlier on Wedder Law, at the head of the Bishaw Burn, confirms the evidence obtained in all the sections as yet visited in the Douglas basin of a marked change in the characters of the limestones and the beds associated with them, at a horizon lying between the Macdonald and Hawthorn Limestones.

The Hawthorn Limestone and those beneath it are generally white, massive and crystalline in character and pass up into marls containing rolled fragments of the underlying limestone. These limestones contain *Lithostrotion junceum* and very large specimens of *Productus giganteus*. The intervening strata consist of variegated grits and marls locally derived from sedimentary and igneous rocks of Old Red Sandstone and Silurian age.

The Macdonald Limestones on the other hand are darker in colour, impure and usually calmy in nature, and are associated with a great thickness of dark blue shales with marine fossils or black carbonaceous shales with clayband ironstones. This difference in the type of the terrigenous deposits and associated limestones points to a change in the physiography of the district at the period represented by the horizon which separates the Hawthorn and Macdonald Limestones. The white limestones and locally derived sediments of the lower group suggest deposit under clear-water coastal conditions during the gradual advance of the sea over the hollows of an earlier land-surface; the impure limestones, dark shales and ironstones of the upper group indicate a later invasion of the area by widely derived river-borne muds forming deltaic, estuarine and marine deposits, upon which the coals of the Carboniferous Limestone Series were eventually laid down.

Attention has already been called[1] to a similar change in the conditions of deposit at the same horizon on the north side of the Lanarkshire basin, and at what is probably, but not yet definitely proved to be the same horizon, at St. Monans, Aberlady and Dunbar.

It is therefore probable that this sudden change in the type of sedimentation above the Hawthorn Limestone indicates more than a local modification of the physiography of the area, and was rather a result of the first complete invasion of the Central Valley of Scotland by the sea. The shallow waters of this protected strait would receive the whole of the finer sediments of rivers which had previously debouched on more open coasts. Some of the ferruginous and carbonaceous muds brought down by the streams before this marine invasion may have been laid down along their course through the Central Valley; the remainder would only locally have found conditions favourable for deposition along the open shore-line. After the marine invasion the river-borne muds would find access to, and a place for sedimentation in, all the hollows in connection with the Central Valley.

[1] 'Summary of Progress' for 1910 (*Mem. Geol. Surv.*), 1911, p. 57.

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COAL MEASURES.

Wishaw District.—The area revised by Mr. Macgregor between Wishaw and Motherwell is occupied by strata lying between the Ell Coal and Skipsey's Marine Band—the top of the Productive Measures. There are a number of quarry sections, and the Hall Gill and Dalzell Burns on their way down to the Clyde from the Lanarkshire plateau have cut deep gorges through the sandstones above the Ell Coal. Otherwise the surface is covered with stiff boulder-clay. The exposure of Skipsey's Band on the north bank of the Clyde at Camps was referred to in last year's Summary.

The structure of this part of the Wishaw Coalfield is well known from the extensive workings in the Thick Ell, Main and Splint seams. The faults are very numerous and often of considerable magnitude; their prevalent direction is north of north-west and their throw generally to the south-west.

INTRUSIVE IGNEOUS ROCKS.

The increasing demand for the valuable road metal supplied by the acid igneous rocks intrusive in the Lower Old Red Sandstone has led to the opening of several new quarries and trial pits in the Lesmahagow district. The evidence thus obtained necessitates some local modification and extension of the boundaries of the areas of intrusion on the existing maps.

In the Dunduff quarry, 2¼ miles north-west of Lesmahagow, a sill of red quartz-felsite with an average thickness of 50 feet and a general inclination to the north, rests upon an extremely uneven surface of discoloured and indurated sandstone. The acid intrusion is traversed from north to south by a vertical dyke, 4 to 12 feet broad, of fine-grained porphyritic basalt, which shows considerable signs of movement along its margin.

The purple micaceous sandstones along the course of the river Nethan at and below Lesmahagow also contain numerous sills of acid rock, varying in texture from a close-grained red or white felsite to a moderately coarse quartz-felspar-porphyry or porphyrite. One of these sills in the river bed near Kerse, shows phenocrysts of quartz, chloritised hornblende, plagioclase felspar and albite, set in a felsitic ground-mass which appears to be composed of quartz and albite.

In the Carboniferous area between Nethanfoot and Auchenheath, a thin sill of quartz-dolerite is proved by bores and shaft sections to be persistent at a horizon from 10 to 14 fathoms below the Index Limestone and at or about the position of the Smithy Coal. The sill is well exposed in the crags on the left bank of the Nethan gorge, below Tillietudlem Castle; it is a fine-grained altered dolerite, approaching a 'white trap,' the augite having entirely disappeared. The Smithy Coal immediately beneath the intrusion is burnt and shows columnar structure. The Gas Coal in the Southfield workings, underlying Draffan, is also burnt over a considerable area; probably by a local intrusion at a lower level, as the sill described above was proved in its usual position.

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Economics.

COAL.

In the area between Wishaw and Camps, Motherwell, the Ell, Main and Splint seams are nearly exhausted, but are still wrought to a small extent in old stoop workings from Shields Colliery. The Pyotshaw and Humph are also workable seams and the Virtuewell is raised at Heathery, Shields and Dalzell Colleries. The Kiltongue is also wrought from Dalzell pit but has still to be opened up over most of the area: where workable it averages about 2 ft. to 2 ft. 6 ins., but may be represented only by two thin seams with a fireclay parting. Of the Drumgray seams two only are known to exceed 1 ft. 6 ins. in thickness. Very little is known as to the Armadale coals in this area, but it is unlikely that any of these are workable under present conditions.

BUILDING STONE.

A number of quarries have from time to time been wrought for freestone to the north of Wishaw in the sandstones immediately above the Ell Coal. The rock quarried is a softish grey and yellowish false-bedded sandstone, in good posts, divided by ribs of 'flakes.'

BRICK CLAYS.

Laminated plastic clays, occupying shallow hollows in the drift, are dug for making draining-tiles and bricks at Blackwood and Whiteshaw near Carluke. At the Wishaw brick-works the fireclays beneath the four-foot coal of Castle Hill and the Smithy Coal at Auchenheath are used in the manufacture of tiles and fire-bricks.

ROAD METAL.

As stated above, there is a large and increasing demand for the intrusive quartz-felsites of the Lower Old Red Sandstone as an excellent material for road metal. The large quarry at Dunduff, near Lesmahagow, supplies nearly the whole of the Middle Ward of Lanarkshire, and the County Council have lately opened quarries at Hazelbank and Stonebyres. The stone is broken to the requisite size in steam crushers at the quarry.

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III.—PETROGRAPHICAL WORK.

(1.)—England and Wales.

In connection with the survey of North Wales some interesting rocks have been sent in from the Denbighshire and Flintshire district and are undergoing investigation. Generally speaking they are rich in soda and are keratophyric in habit.

In the Midland District Mr. Barrow has paid considerable attention to the Triassic and Carboniferous sedimentary deposits, and has prepared many samples for microscopic examination. The sediments have been separated into a number of samples of different specific gravity, and a detailed investigation will be undertaken as soon as the collections are more complete.

Mr. Dewey, in the London District, has collected widely for the same purpose from the Eocene deposits.

In the early part of the year Mr. Thomas visited an interesting auriferous locality in North Wales and drew up a report on the lodes. The mine, known as the Prince Edward Mine, is situated about 2½ miles north-east of Trawsfynydd station on the Bala-Ffestiniog railway. The lodes are all highly siliceous and consist mainly of white vein-quartz charged with metallic sulphides. They follow approximately the strike and dip of the country rock (Cambrian) and almost invariably have sedimentary rock beneath and a diabase-intrusion above forming the hanging-wall. Locally they carry visible gold, but in the body of the lodes the gold is presumably held by the pyrites. It is quite evident that the formation of the lodes is controlled by the diabase-intrusions, but their formation was long subsequent to the igneous intrusion and was dependent on differential movement between the hard and soft rocks accentuating original planes of weakness.

Dr. Flett has examined and reported upon a large series of rocks collected in Bardsey Island and presented to the Survey by Dr. Matley, and the results of his investigation have recently been communicated to the Geological Society.[1]

A collection of boulders from the Wolverhampton district have been submitted for examination by Dr. J. A. Codd. Amongst these it has proved possible to identify the well known granites of Eskdale, Criffel, and Dalbeattie, the granophyre of Ennerdale, and several other rocks of northern origin. The collection also includes keratophyres, soda-trachytes, and albite-diabases which are closely allied to rocks from the Snowdon and Arenig region of North Wales. It would appear that these erratics were brought to the Wolverhampton district by a lobe of the Irish Sea Ice which passed in a south-easterly direction over the relatively low-lying ground of the Cheshire Plain and bordering country.

A temporary exhibit has been prepared by Mr. Dewey to illustrate the recently published memoir on the Geology of the Lizard Peninsula by Dr. J. S. Flett and Mr. J. B. Hill. This exhibit includes specimens of all the principal rock-types with labels describing their petrographical characters and their relations to

[1] *Quart. Journ. Geol. Soc.*, vol. lxix, 1913.

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one another. The exhibit also includes maps and photographs showing the mode of occurrence of the rocks in the field and their influence upon the scenery. A section has been reserved for the economic geology and mineralogy of the district.

(2.)—SCOTLAND.

Petrographical work during 1912 was carried on chiefly in connection with the districts of Argyll and Ayrshire. In the early part of the year Mr. Thomas and Mr. Bailey classified the extensive collections of Tertiary igneous rocks which had accumulated in previous years from the Island of Mull and Morven. As is well known there is a close parallelism between the petrology of Mull and of those portions of Skye and the Small Isles of Inverness so well described by Mr. Harker. It is interesting to record that the resemblance holds in many matters of detail, and that allivalites and mugearites have been found in Mull, though not, as yet, to any great extent. At the same time it has appeared desirable to establish certain new types in the Mull region and material has been collected in order that the definition of these types may be accompanied by chemical analyses. The results obtained in this direction, however, are not quite ready for publication.

A close connection has been maintained throughout between microscopical investigations and field-work, and in various instances the results of last year's work in the Petrographical Department will be found embodied in the field-descriptions.

Mr. Thomas has made a study of the sapphire-bearing rocks (p. 48) collected by Messrs. Anderson, Tait, and Wilson in Mull. The minerals in the xenoliths are chiefly pale blue sapphire, dark green spinel, rose-pink plechroic sillimanite, anorthite, deeply-coloured hypersthene, green monoclinic pyroxene, and some others as yet undetermined. The felspar occurs in large plates, and is often coloured either pale blue or pale pink by finely distributed sapphire or sillimanite. The pyroxenes occur as clots, often of considerable size. As a result of the microscopical investigation it is felt that further examination of these rocks in the field should be undertaken in 1913 before any definite views are expressed as to their exact nature and origin.

Dr. Flett has examined and described a large collection of rocks made by Drs. Horne and Peach in the Isle of Lewis. The dominant rock of the island appears to be hornblende-gneiss with subordinate biotite-, muscovite-biotite-, and pyroxene-gneisses. These rocks have close affinities with the gneisses of Western Sutherland and Ross but they present a facies which is not exactly similar to that of any other district in Scotland. The region differs in the preponderance of hornblende-gneisses, the scarcity of pyroxene-gneisses, the absence of pyroxene-granulites and eclogites, and in the general prevalence of cataclastic structures.

Dr. Flett has also contributed reports on collections of rocks from the Aberdour and Burntisland District for Dr. Matley, on rocks from Midlothian and Fife, and on an extensive series collected by Dr. Horne from the district of Portsoy.

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The igneous rocks of the Portsoy area belong to two series, a basic and ultrabasic series consisting of serpentine and gabbro, and an acid series of gneisses, an assemblage similar to that met with in other parts of Britain such as Skye, and the Lizard District of Cornwall. These rocks belong to an older or 'pre-foliation' series, for they are all sheared although they do not show the ultimate phases of metamorphism. The least altered rocks are the acid veins of graphic granite, and this is in accordance with the field-observations that they are the youngest members of the complex. The sediments belong to the Banffshire series and exhibit their well marked lithological characters. Most of them have suffered contact-alteration and there are indications that this alteration has been followed by a period of shearing. The post-intrusion movements in this district, however, have not been of very great magnitude.

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IV.—CHEMICAL WORK.

The following are analyses of rocks from the Isle of Mull. (1″ Sheet 44. Scotland.) Six of these (Slice Nos. 14821*a*, 14824, 14825, 14841, 14843, 14846) were completed in 1911, but their publication has been delayed until the petrographical work of this sheet was more advanced. They are now given together with seven from this sheet completed in 1912.

14821a. *Trachyte*, from the central portion of a volcanic neck at Braigh a' Choire Mhoir, 1 mile W. of Salen, Mull. The rock is fine grained, has well-developed fluxion structure, and is composed mainly of microlites of alkali-felspar.

14824. *Trachyte*. One-mile NE. of Loch Bà, 2 miles E. of Gruline House, Gruline, Mull.

14825. *Augite-rhyolite*. Intrusive rock from the top of a deep gorge situate ¾ mile N. of E. of the summit of Beinn a'Ghràig, Mull. The phenocrysts consist of alkali-felspar, microperthite, greenish-augite, and dark green mica. The ground-mass was glassy but has undergone partial devitrification. The rock contains minute xenoliths composed of olivine and basic plagioclase.

14841. *Augite-granophyre*. Intrusive rock from Beinn Bheag, ¼ mile S. of Knock, Gruline, Mull.

Slice No. ...	14821A.	14824.	14825.	14841.
Lab. No. ...	368.	369.	370.	371.
SiO_2	63·12	53·78	72·66	73·32
TiO_2	·51	2·28	·34	·51
Al_2O_3	15·44	12·69	12·00	12·25
Fe_2O_3	1·73	3·44	2·03	2·77
FeO	3·53	8·94	2·04	2·20
MnO	·27	·53	·18	·12
(CoNi)O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	nt. fd.	·09	·12	·09
CaO	1·31	6·36	1·25	1·65
MgO	·62	2·58	·07	·11
K_2O	5·36	2·27	5·26	2·34
Na_2O	5·81	2·74	3·26	3·92
Li_2O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·14	1·19	·22	·35
H_2O above 105° C. ...	·44	2·19	·47	·35
P_2O_5	·25	·55	·04	·10
FeS_2	nt. fd.	·42	nt. fd.	nt. fd.
CO_2	1·89	·08	·24	·06
Cl	—	—	—	—
Total ...	100·42	100·13	100 18	100·14

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14843. *Granophyre*, coarse-grained, from Benmore Lodge, W. end of Loch Bà, Mull. The rock consists of orthoclase, micro-perthite, quartz, greenish augite, and magnetite.

14846. *Gabbro* from Leac an Leathaid, ⅝ mile WNW. of the summit of Beinn na Duatharach, Mull.

15996. *Tholeiite-pitchstone*. Glassy portion of inclined-sheet exhibiting sheath-and-core structure, from an exposure ¼ mile NNE. of Mullach Glac an t'Sneachda, nearly 2 miles SSW. of Pennygael, Mull. Brown glass with sub-variolitic augite, and basic plagioclase.

15997. *Tholeiite-pitchstone*. Stony portion of the same sheet, same locality. The rock is slightly richer in augite, and contains a less proportion of glass.

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Slice No. ...	14853.	14846.	15996.	15997.
Lab. No. ...	372.	373.	384.	385.
SiO_2	73·12	48·34	61·69	59·21
TiO_2	·39	·95	1·00	1·06
Al_2O_3	12·44	20·10	14·43	14·06
Fe_2O_3	2·09	1·97	1·23	2·66
FeO...	1·65	6·62	5·86	4·87
MnO	·17	·32	·30	·24
(CoNi)O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	nt. fd.	·10	·04	·03
CaO	·88	13·16	4·97	5·95
MgO	·14	5·49	2·81	3·71
K_2O	4·67	·98	1·72	2·83
Na_2O	3·90	1·66	3·20	2·06
Li_2O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·25	·02	·25	2·06
H_2O above 105° C. ...	24	·44	2·32	1·49
P_2O_5	·09	·04	·24	·20
FeS_2	nt. fd.	nt. fd.	nt. fd.	nt. fd.
CO_2	·05	·11	—	—
Cl	—	—	·02	—
Total ...	100·08	100·30	100·08	100·43

ANAL. E. G. RADLEY.

15989. *Inclined sheet of Inninmore Type.* Near head of stream which runs from Tom a Cloilich, ½ mile SW. of Pennygael, Mull. Dark glassy rock with minute phenocrysts of an augite which has a very small angle between the optic axes.

It is hoped that, later, an analysis of this uncommon augite will be published together with the optical properties.

15990. *Inclined sheet of Inninmore Type,* from a point $\frac{3}{16}$ mile SW. of Trig. Sta. on N. end of Beinn an Lochain, nearly 1 mile SSW. of Pennygael, Mull. Similar to the above but contains small phenocrysts of basic plagioclase, and has acicular augite in the glassy base.

Slice No. ...	15989.	15990.
Lab. No. ...	386.	387.
SiO_2	62·37	64·13
TiO_2	1·06	1·19
Al_2O_3	12·04	13·15
Fe_2O_3	1·87	1·08
FeO	5·81	6·31
MnO	·24	·27
(CoNi)O	nt. fd.	nt. fd.
BaO	·07	·09
CaO	3·51	3·62
MgO	·97	1·08
K_2O	2·34	2·32
Na_2O	3·47	3·64
Li_2O	nt. fd.	nt. fd.
H_2O at 105° C.	·44	·36
H_2O above 105° C. ...	5·54	2·71
P_2O_5	·30	·31
FeS_2	nt. fd.	nt. fd.
CO_2	—	—
Cl	—	—
Total ...	100·03	100·26

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15991. *Alkali-syenite* from the N. side of the island of Garnhnach Mhor, Carsaig Bay, Mull. A yellowish grey rock of medium grain, composed of soda-orthoclase, aegerine, aegerine-augite with mantles of aegerine, arfedsonite, barkevikite, pseudomorphs after olivine, and accessory magnetite and apatite. No nepheline has been detected.

15994. *Felspathic olivine-dolerite* from the hillside between the two streams to the south of Coire Buidhe, Mull. The olivine is partly decomposed, the augite is titaniferous, and iron-ore is plentiful.

15995. Fine-grained non-porphyritic *Basalt*, from stream at pit, ⅛ mile NNE. of Pennycross House, Mull. The olivine is fairly fresh, and the augite is deeply coloured, probably titaniferous.

Slice No. ...	15991.	15994.	15995
Lab. No. ...	388.	389.	390.
SiO_2	58·81	45·54	45·37
TiO_2	·76	1·06	2·87
Al_2O_3	14·81	23·39	15·16
Fe_2O_3	4·58	1·98	3·38
FeO	4·21	6·98	11·58
MnO	·27	·27	·31
(CoNi)O	nt. fd.	nt. fd.	nt. fd.
BaO	·03	nt. fd.	nt. fd.
CaO	2·33	11·82	8·11
MgO	·80	4·60	6·72
K_2O	4·96	·44	·44
Na_2O	5·60	2·50	2·90
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	2·00	·62	1·18
H_2O above 105° C.	·82	·72	1·96
P_2O_5	·20	·13	·29
FeS_2	nt. fd.	nt. fd.	nt. fd.
CO_2	—	—	—
Cl	—	—	—
Total ...	100·18	100·05	100·27

ANAL. E. G. RADLEY.

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V.—PALÆONTOLOGICAL WORK.

(1.)—England and Wales.

Large suites of Cretaceous and of Tertiary fossils have been determined in the palaeontological department. Other specimens named include *Lingula* and *Orbiculoidea*, probably of new species but too fragmentary for description, from rocks presumably of Cambrian age from a boring at Lowestoft (*vide* Appendix III, p. 87).

Clonograptus was obtained from a boring at Calvert in Buckinghamshire. *Clonograptus*, one of the genera of graptolites with numerous uniserial stipes produced by repeated dichotomous division, occurs sparingly in Britain. The specimens from the Calvert boring are well preserved, and are referred to *C. tenellus*, var. *callavei* [=*Bryograptus callavei* Lapworth]. The discovery at Calvert of this variety, only known from the Shineton Shales of Shropshire hitherto, is of considerable interest since it leaves no doubt as to the occurrence of Tremadoc rocks within a short distance of London. The information obtained from an examination of the cores at Calvert has been utilised by Dr. A. M. Davies and Mr. J. Pringle in an account of the rocks passed through in the boring, recently read before the Geological Society.

A boring at Chilham, in Kent, provided a series of *Monograptus* in an exceptionally good state of preservation. These graptolites prove the rocks there met with to be of Tarannon age. The specimens have been submitted to Dr. Gertrude Elles for description.

At Camp Hill Grange Quarry, in the Nuneaton district, where the Olenellus Fauna was known to occur, no specimen of the *Olenellus* family had been recorded. The red shales of that quarry have now yielded to Mr. Pringle fragments which have been ascribed by Mr. Ph. Lake to *Callavia*.

Among the additions to the fossil galleries attention may be directed to the following: A cast of a human skull from Galley Hill, Kent. Some three thousand specimens, from the collection of fossils presented by the Geological Society of London, have been named and placed in their stratigraphical position as far as space permits. These include large casts of typical Mesozoic reptiles, also a series of Cephalopoda from the Cretaceous rocks, being part of the type specimens used in illustration of Daniel Sharpe's monograph on "The fossil Remains of Mollusca found in the Chalk of England," Palaeontographical Society, London 1853-1856.

Suites of fossils have been selected and are exhibited in special cases to illustrate memoirs recently published.

A list of donations to the Museum will be found on p. 76.

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The following specimens in the Museum have been figured and described during the year:—

IN THE PALÆONTOLOGICAL SOCIETY'S VOLUME FOR THE YEAR 1911. (Published 1912.)

Cretaceous Lamellibranchia of England.

By MR. HENRY WOODS, M.A.

Inoceramus costellatus *Woods*, pl. liv, figs. 6a, b, c, 7, p. 336.
,, balticus *Böhm*, text-figs. 52, 53 (2 views), pp. 294, 295
,, lamarcki *Park.*, text-fig. 85 (2 views), p. 325.

Fossil Fishes of the English Chalk.

By DR. A. SMITH WOODWARD, F.R.S.

Apateodus striatus *A. S. Woodw.*, pl. liv, figs. 4, 4a, p. 246.

The Ganoid Fishes of the British Carboniferous Formations

By DR. R. H. TRAQUAIR, F.R.S.

Myriolepis hibernica *Traq.*, pl. xxxvi, fig. 3, p. 162.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, Vol. LXVIII.

By MRS. LONGSTAFF, F.L.S.

Foordella hibernica *Longstaff*, pl. xxix, fig. 4, p. 301.
Pithodea percincta (*Portl.*), pl. xxx, fig. 4, p. 305.

IN THE GEOLOGICAL MAGAZINE, Dec. 5, Vol. IX.

By MR. F. R. COWPER REED, M.A.

Dionide atra *Salter*, pl. xi, fig. 1, p. 200.

IN THE MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN. PALÆONTOLOGY, Vol. I., Part 3.

The British Carboniferous Trepostomata.

By DR. G. W. LEE, F.R.S.E.

Stenopora castletonensis *Lee*, pl. xv, figs. 9, 10, p. 158.
Tabulipora sp., pl. xiv, fig. 6, p. 165.
,, tenuimuralis *Lee*, pl. xv, fig. 25, p. 169.
,, sparsitabulata *Lee*, pl. xv, fig. 31, pl. xvi, fig. 1, p. 171
,, crassimuralis *Lee*, pl. xvi, figs. 5, 6, p. 172.
,, multitabulata *Lee*, pl. xvi, figs. 3, 4, p. 173.
Dyscritella nana *Lee*, pl. xvi, figs. 18-20, p. 179.

IN THE MEMOIRS OF THE BOSTON SOCIETY OF NATURAL HISTORY, Vol. VII., Boston, U.S.A., 1912.

Phylogeny of the Echini, with a revision of Palæozoic Species.

By PROF. ROBERT TRACY JACKSON.

Archaeocidaris urii (*Fleming*), pl. xiv, figs. 16, 20a, b, c, pl. xv, fig. 1, p. 276.
Echinocystites pomum *Wyville Thomson*, pl. xvi, fig. 4, p. 252.

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Palaeechinus elegans *M'Coy*, pl. xxx, fig. 11, pl. xxxi, fig. 5, p. 308.
Maccoya phillipsiae (*Forbes*), pl. xxxiii, figs. 13, 14, p. 316.
Lovenechinus lacazei (*Julien*), pl. xxxvi, figs. 1-3, p. 326.
,, anglicus *Jackson*, pl. xlvi, figs. 5, 6, pl. xlvii, figs. 3-5, p. 346.
Melonechinus keepingi *Jackson*, pl. lviii, fig. 1, pl. lix, figs. 1-3, p. 384.
,, ,, text-fig. 237, p. 231.
,, etheridgii (*Keeping*), pl. lviii, figs. 3, 4, pl. lix, figs. 5, 6, 8, p. 385.
Lepidesthes devonicans *Whidb.*, pl. lxviii, figs. 15-17, p. 420.
Pholidocidaris tenuis *Torng.*, pl. lxxii, fig. 11, p. 440.
,, acuaria (*Whidb.*), pl. lxxiv, fig. 11, p. 441.
Perischodomus biserialis *M'Coy*, described p. 405. (4 specimens.)

(2.)—Scotland.

The fossils collected in connection with the field-work are from the Carboniferous areas of Central Scotland and the Mesozoic and Tertiary rocks of Mull, while a special collection was made from a fossiliferous band in the Highland Border Rocks near Aberfoyle. Many of the specimens have been examined by Dr. G. W. Lee, while the Carboniferous plants, the Mesozoic cephalopods and brachiopods and some Carboniferous lamellibranchs have been named by Dr. Kidston, Mr. S. S. Buckman, and Dr. Wheelton Hind respectively.

The fossils collected by Mr. D. Tait from the Highland Border Rocks near Aberfoyle have not yet been studied in detail. They are mostly hingeless brachiopods presumably of the same age as the Stonehaven fauna, which is tentatively referred to the Upper Cambrian.

Carboniferous Rocks.—The fauna of Pendleside facies occurring at the top of the Calderwood Glen and described in the "Summary of Progress" for 1910, p. 65, is found by Mr. Carruthers to be represented in the Strathavon district, below Cot Castle, on the banks of the Avon Water. The list of the fossils collected there by Mr. D. Tait is very extensive, and contains a large number of species not found at Calderwood. *Pterinopecten papyraceus* (J. Sow.) was not found, but *Posidonomya becheri* (Bronn), numerous goniatites, and the fine-ribbed *Bucanopsis* cf. *marcouana* (Gein.) are common to both localities.

The same horizon has also yielded a suite of plants, which were submitted to Dr. Kidston, who supplied the following remarks:—

"The collection contained 38 specimens, but a considerable proportion of the fossils were very fragmentary and badly preserved. The following species were, however, determinable.

1. *Sphenopteris* cf. *Gersdorfii* Goepp. sp. (*Hymenophyllites Gersdorfii* Goepp. *Syst. Fil. Foss.*, p. 257, pl. xxxvii, figs. 1–2, 1836).
   Among the fossils is a small but very well preserved fragment of a minute *Sphenopteris*, which, if not the *Sphenopteris Gersdorfii* Goepp. sp., is very closely related to it.
2. *Sphenopteris n. sp.* This is the same species as No. 2 in the list of fossil plants from the East Kilbride district given in the "Summary of Progress" for 1910, p. 65.
3. *Sphenopteris sp.* In addition to the above there are fragments of at least two other species of *Sphenopteris* but they are too imperfectly preserved to admit of a satisfactory determination.

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4. *Sphenopteridium sp.*
5. *Rhodea moravica* Ett. sp. This specimen came from the roof of a one foot coal, which is about 24 ft. above the bed that yielded the other plants given in this list, except one of the species of *Sphenopteris* included under No. 2 above.
6. *Archaeopteris Tschermaki* Stur.
7. *Archaeopteris Dawsoni* Stur.

In regard to these two species, see the note given in the "Summary of Progress" for 1910, p. 66.

8. *Telangium affine* L. & H. sp.
9. *Telangium bifidum* L. & H. sp.

The species in the above list clearly indicate a Calciferous Sandstone age for the beds from which they were derived, and though the list does not contain so many species as those obtained from the East Kilbride locality (l. c. p. 66), there can be no doubt that the two localities are on or about the same horizon, as their flora is practically identical."

A Memoir on the British Carboniferous Trepostomata, by Dr. G. W. Lee, was issued in May.[1] It was written with the object of making known a group of fossils which is well represented in the British Lower Carboniferous rocks, and likely to prove of value in zonal work. Several of the species described appear to be reliable indices of certain horizons.

Further study of the sequence of life-zones in the Jurassic Rocks of Mull, based on material collected during this and previous years, has led to the following results:—

Lower Lias.—In Mull the Lower Lias beds are not favourable to zonal studies, with the exception of the top members of the series in Carsaig Bay. There, the low-water flats of the east side of the Bay yield a number of ammonites characteristic of the Raricostatum Zone. They occur in black nodules and Mr. Buckman finds that they are curiously like the condition of similar *Echioceras* species from Radstock in Somerset. The great number of species is also a remarkable feature of this fauna.

The characteristic fossils of the Jamesoni Zone on the west side of Carsaig Bay are *Gryphaea cymbium* Lamarck, and an *Uptonia* which Mr. Buckman refers to *U. bronni* (Roemer).

Upper Lias.—The Upper Lias was found to occur in the Carsaig district, where Dr. G. W. Lee detected a small patch just above the old Nun's Pass Quarries. It consists mainly of soft blue shale at the base of which Mr. Tait noticed a thin foetid limestone. The Exaratum Zone is indicated by Ammonites—*Harpoceras* and allied genera—occurring at the base of the series, immediately above the Middle Lias white sandstone. Ten feet higher up in the section the fauna consists mainly of species of *Dactylioceras*. Mr. Buckman considers that this suite of ammonites indicates a zone above the Falcifer Zone, that is, the Bifrons Zone in a general way—with some indication of Fibulatum Zone in particular. In the gap below the Falcifer Zone may be expected.

Lower Oolites.—Much has been added to our knowledge of the sequence of life-zones in the Mull Lower Oolites. In particular

[1] *Mem. Geol. Surv.* Palaeontology. Vol. I, Part 3, 1912.

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the elucidation of an obscure point has afforded striking confirmation of the persistence and regular sequence of the zones established by Mr. Buckman.· Two suites of ammonites collected in 1910 at Port Donain were referred to zones which, from the field evidence as then interpreted, appeared to occur in inverted order. The collecting ground consisted of limestone bands in apparently normal succession, with a pronounced dip, and each band had been collected from separately. Yet the band containing fossils of Concava age was higher than that which yielded fossils of Discitae age. Reference to this anomaly was deferred till re-examination of the ground could be made, when closer examination revealed the fact that the band with Concava fossils had been brought into its present position by faulting and subsequent tilting producing a deceptive appearance of normal superposition. The materials collected last season by Mr. Tait have also enabled Mr. Buckman to recognise zones which had so far been unrepresented in the collections made in previous years. We have now in the Loch Don district a fairly complete sequence of the Lower Oolite life-zones from the Opaliniforme Zone to the Garantiana Zone. The Opaliniforme, Scissum, Ancolioceras and Murchisonae Zones occupy a small thickness of limestone in the Ardnadrochet Glen. Some twenty feet of limestone at Port nam Marbh —overlying strata from which no zonal fossils could be obtained— contain the Bradfordensis, Concava, Discitae, Sauzei and Blagdeni Zones. This is succeeded by fifty feet of hard, mottled sandstone which may, in part, have been deposited in Niortensis time, since it is overlain by a limestone containing an ammonite indicating the Garantiana Zone.

Callovian.—Opportunity may be taken here of correcting a misprint which obscures the list of Callovian fossils on p. 62 of last year's "Summary." The species of *Cosmoceras* are *C. elizabethae* (Pratt) [Quenstedt] and *C.* cf. *spoliatum* (Quenstedt). Mr. Tait made a further collection from the same bed, which contains an additional form, namely *Reineckeia straussi*? Parona and Bonarelli.

The following specimens in the Survey Collections have been figured and described during the year:—

In the Memoirs of the Geological Survey.

Palæontology, Vol. I., Part 3.

By Dr. G. W. Lee, F.R.S.E.

Stenopora redesdalensis *Lee*, pl. xv, figs. 1, 2, p. 153.
,, haddingtonensis *Lee*, pl. xv, figs. 3, 4, p. 156.
,, obliqua *Lee*, pl. xv, fig. 5, p. 159.
,, tenuipora *Lee*, pl. xv, figs. 6, 7, p. 161.
Tabulipora scotica *Lee*, pl. xv, fig. 12, p. 162.
,, howsei (*Nich.*), pl. xv, fig. 22, p. 166.
,, tenuimuralis *Lee*, pl. xv, fig. 26, p. 169.
Dyscritella ambigua *Lee*, pl. xvi, figs. 11, 12, p. 181.
Koninckopora inflata (*de Koninck*), pl. xvi, figs. 21–23, p. 182.

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VI.—MUSEUM OF PRACTICAL GEOLOGY.

A Guide to the Gemstones in the mineral collections by Mr. W. F. P. McLintock has been published. It has been designed to serve not only as a companion to the collections in the Museum but also as an elementary handbook to the subject of precious stones.

Temporary exhibits have been arranged to illustrate Memoirs on The Geology of the Country around Ollerton, The Geology of the Country around Tavistock and Launceston and the Mesozoic Rocks in some Coal Explorations in Kent.

Loan exhibits have been accepted from the Government of New South Wales and Messrs. F. Wiggins & Sons. The former is an important series of minerals from the famous Broken Hill District; the latter is a valuable collection of micas. Both collections have been arranged in the Hall.

List of Donations during the year 1912.

Bailey, E. B., Esq., B.A.—90 Rocks from Sweden.

Barratt, W., Esq., F.L.S.—A specimen of *Homalonotus* from the Staddon Grit above Bedruthan Steps, and one of *Pteroconus mirus* Hinde, from the Devonian of Bedruthan, Cornwall.

Bishop, Major C. F., R.A.—A specimen of *Nymphaster* from the Terebratulina Zone at the Harbour Works, Dover.

Bright, J. H. R., Esq.—A tooth of *Elephas primigenius*, Blum., from the Gravel at Grimley, near Worcester.

Bristol Museum and Art Gallery.—A series of fossils from the Coal Measures of the Bristol Coalfield.

British Flint Pebble Co.—(*See* Johnson, G. E. M.)

Bromehead, C. E. N., Esq., B.A.—A series of *Neritina gratelupana* (Fer.) and *Valvata piscinalis* (Mull.) from the Shell Pit, Swanscombe.

Budd, E., Esq.—Magnetite from Kaapruinden, and Tourmaline from Jamestown.

Bullbrook, J. A., Esq.—Specimens of Quartzite from Ightham, Kent.

Burt and Burt, Messrs.—(1) Purbeck Cliff Stone, (2) Langton Roofing Tiles, (3) Swanage Roofing Tile, (4) Samples of Langton Freestone.

Carus-Wilson, C., Esq.—Calcite in large crystals from the Chalk near Bournemouth.

Christy, W. H., Esq.—Cassiterite from Bolivia.

Clarke, J. O., Esq.—Two specimens of sulphur including crystals from the Makushion volcano, Unalaska Island, Alaskan Archipelago.

Codd, Dr. J. A.—19 specimens of erratics from Staffordshire.

Cooke, H. J., Esq.—Specimens of Magnesite from Asia Minor.

Cookson, C., Esq. (Messrs. Cookson and Co., Ltd.).—Pseudomorphs of Antimony oxide after Stibnite, from the Catorce, State of San Luis, Potosi, Mexico.

Cooper, and Sons, Messrs. J. R.—Three bricks and four tiles from the Brickworks, Maidenhead. Also samples of the clay and sand used there.

Cudmore, E., Esq.—Specimens of Antimony and Galena from Australia.

Darley and Butler, Messrs.—Rough Corundum from Ceylon.

Edwards, E. W. J., Esq.—A sample of stone from the new island off Trinidad.

Fielding, Messrs. J. and W.—Samples of Building-stones, J. F. A. Brand of Mottled or Shaded Alton, Adam Bede Brand.

Geological Society of London, The.—A series of specimens and 35 slides of Greenstones from Eastern and Central Cornwall, from the Collection of the late J. A. Phillips, Esq.

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GILBERT, E. G., ESQ.—Specimens of "Bantams," &c. from South Africa.
GODSON, C., ESQ.—A specimen of Olivine lava from the Azores.
HAMPTON, MAJOR.—Massive Corundum, from Nagpur, India.
HARRIS, A., ESQ.—Specimen of Silicified Wood from Arizona.
HASLUCK, F. W., ESQ.—Lava bearing casts of olive leaves from Santorin.
INOUYE, DR. K.—Specimens of Sulphur containing Selenium.
JAMESON, MAJOR A.—Flint implement from Lee-on-Solent.
JOHNSON, G. E. M., ESQ.—Samples of "Flint Pebbles."
JONES, PICKEN, AND BROWN, MESSRS.—Specimen of Iron Ore from Caraca, State of Minas Geraes, Brazil.
KAOLIN CORPORATION, LTD., THE.—Samples of China—and other Clays from Retew, Cornwall.
KELSEY, A. F., ESQ.—Sample of Bituminous sand, from near McMurray, Athabasca.
KELTIE, DR. J. S., F.R.G.S.—Three specimens of stone from the new island off Trinidad.
LLOYD, H. G., ESQ.—Specimen of Vivianite from Abbey Mills, London, E.
MACALISTER, D. A., ESQ., A.R.S.M.—Specimens of Tin ore from Kit Hill and Birch Tor.
MATLEY, DR. C. A.—22 Rocks from Bardsey Island, North Wales.
MCLINTOCK, W. F. P., ESQ., B.SC.—A series of specimens of minerals from the Granite of Lundy Island.
MEYERKORT, R. W., ESQ.—Specimens of Gossan from Newfoundland.
MONCKTON, H. W., ESQ., F.G.S., &c.—A Whetstone (brynesten), from Eidsborg, Norway.
MORROW-CAMPBELL, J., ESQ.—A specimen of Cellular quartz from the Bosmo Mine, Norway.
NEWTON, W. M., ESQ.—A tooth of *Equus caballus*, Linn., from the Brick-earth of Crayford.
NUTT, A. Y., ESQ.—Samples of Sarsen or Heath Stones from Buckingham-shire; also a series of building stones used in Windsor Castle.
OLDEN, C., ESQ., F.G.S.—Four photographs of the Muzo Emerald Mine.
OTTER COPPER CO., MESSRS. THE.—Specimen of Copper Ore from Kilfinan, Argyll.
PERCIVAL, S. G., ESQ.—(1) Specimen of Galena from the Mendip Hills, (2) Eisenkiesel from Ashdown Quarry, Weston-super-Mare, (3) Brown Calcite from Lawrence Weston Quarry, Gloucestershire, (3) Calcite enclosing quartz from near Bristol, Somersetshire.
PHILLIMORE, R. G., ESQ.—A sample of Pudding Stone from Radlett, Hertfordshire.
POWELL, F. M., ESQ.—Specimens of Copper Ore, from Dundas, Australia, and Phosphates from Christmas Island.
RATHBUN, DR. RICHARD.—United States National Museum, Washington, D.C., (1) A set of Plans and sections of the New Buildings, United States National Museum, (2) A set of photographs of the interior, (3) Blue prints of the Standard Museum Cases, (4) Samples of rack and bracket for shelf supports.
RENTON, E., ESQ.—Large crystal of spinel.
REYNELL, A., ESQ.—A specimen of Chalybite from the Perran Iron Mine.
REYNOLDS, PROF. S. H., M.A., &c.—Fourteen specimens of Irish rocks from Kilbride, Co. Mayo.
RICHTER, F. W., ESQ.—Various Mineral specimens, including Haematite.
SAUNDERS, MESSRS. J. AND W. J.—Samples of Brick and Shale from the Pinhoe Works, near Exeter.
SCHERTELL, F., ESQ.—A series of specimens of Bavarian Minerals.
SCORESBY-ROUTLEDGE, W., ESQ., M.A.—A series of sands from the Kenia Province, British East Africa.
SEARLE, G. A., ESQ.—A specimen of *Spirifer subradiatus*? Sow., from near Hobart, Tasmania.
SIBLY, DR. T. F.—Two specimens of *Productus fimbriatus*, J. de C. Sow., two of *P. pustulosus*, Phill., one of *P. punctatus* and one of *Productus sp. nov.* from the Carboniferous Limestone (D_2) of Park Hill, Derbyshire.
SMITH, B., ESQ., M.A., &c.—Two specimens of sand rock with phosphatic nodules.
SOFNAL, MESSRS., LTD.—Sample of "Allagit" used for water-softening.

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STONE AND CO., LTD., MESSRS.—A sample of "N.N." Firebrick; also raw material.

SURREY AND CO., LTD., MESSRS.—Sample of "Raw Silica;" also of "Calcined Silica" from Threebarrow Hill, Sunningdale, Berks.

TAYLOR AND CO., MESSRS.—Specimen of red Corundum from Siberia.

TULLEY, MESSRS. W.—A block of green mica from Madras.

TUNBRIDGE, E. W., ESQ.—Three photographs of the Slate Quarries Norheim, Vorse, Norway.

VOELCKER, DR. A.—(1) Sample of Greensand from Husborne Crawley, Bedfordshire, (2) Specimens of Fahlerz and of Copper Ore.

VOELCKER AND SONS, MESSRS. A.—A series of samples of foreign phosphates

WADE, DR. A.—Specimens of Arabian Rock Salt and Gypsum.

WHITE, MRS.—A specimen of Copper Ore from Jamaica.

WIGGINS AND SONS, MESSRS. F.—Specimens of Mica from Canada and the Argentine.

WILSON, G. V., ESQ.—Three specimens of Mosedale rocks, Cumberland.

ZEMJATSCHENSKY, PROF. P.—Six samples of Russian Kaolin.

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VII.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

(A.) BRITISH ISLANDS.

I.—MAP.

Twenty-five miles to One-inch Map.

(Colour-printed, price 2*s*.).

Map of British Isles. 2nd Edition.

(B.) ENGLAND AND WALES.

I.—MAPS.

(*a*.) *One-inch Maps* (*New Series*).

(Colour-printed, price 1*s*. 6*d*. each.)

Sheet 338, Dartmoor (Drift).
Sheet 359. Lizard (Drift).

A colour-printed Drift Edition of the following Sheets has been issued in place of the hand-coloured edition:—

Sheet 52 [Old Series 96 S.W.], Ripon and Thirsk.
Sheet 325, Exeter.
Sheet 355, Kingsbridge.
Sheet 356, Start Point.

(*b*.) *Six-inch Reference Maps.*

Twenty-one MS. coloured copies of six-inch quarter sheets have been made from the field-copies, and deposited in the Library for public reference.

These are as follows:—

Cornwall.—75 SE.; 76 NW., NE., SW., SE.; 77 SW.; 80 NW., NE., SW., SE.; 81 NW., NE., SW., SE.; 84 NW., NE., SW., SE.; 85 (NW. and SW.), 85 NE.; 90 NE.

Forty-four Standards of six-inch quarter sheets have been made from the field-copies, and deposited in the Strong Room.

These are as follows:—

Berkshire.—31 NW., NE., SW., SE.; 32 NW., SW., SE.; 39 NW., NE., SW., SE.; 40 NW., NE., SW.; 47 NW., 47 (NE. and SE.), 47 SW.; 48 NW.

Buckinghamshire.—42 NW., NE., SW., SE.; 43 NW., SW., SE.; 47 NW., NE., SW., SE.; 48 NW., NE., SW., SE.; 51 NE.; 52 NW., NE.; 53 NW., SW.; 55 NE., SE.; 56 NW., SW., SE.; 58 NE.

II.—MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1911. pp. 90. 4 illustrations. Price 1*s*.

Guide to the Collection of Gemstones in the Museum of Practical Geology. By W. F. P. McLintock, B.Sc. pp. 92, 43 illustrations. Price 9*d*.

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The Water Supply of Surrey from Underground Sources, with Records of Sinkings and Borings. By W. Whitaker, B.A., F.R.S., with contributions on the Rainfall by H. R. Mill, D.Sc., LL.D. pp. 352, 1 map. Price 7*s*.

The Geology of the South Wales Coalfield. Part III. The Country around Cardiff, with a Geological Bibliography of South Wales and Monmouthshire. (Explanation of Sheet 263.) By A. Strahan, M.A., Sc.D., F.R.S., F.G.S., and T. C. Cantrill, B.Sc., F.G.S. Second Edition. pp. 157, 13 illustrations. Price 2*s*.

The Geology of the Country around Winchester and Stockbridge. (Explanation of Sheet 299.) By H. J. Osborne White, F.G.S. pp. 89, 12 illustrations. Price 1*s*. 6*d*.

The Geology of Dartmoor. (Explanation of Sheet 338.) By Clement Reid, F.R.S., G. Barrow, F.G.S., R. L. Sherlock, D.Sc., F.G.S., D. A. MacAlister, A.R.S.M., H. Dewey, F.G.S., and C. N. Bromehead, B.A., F.G.S. with contributions by J. S. Flett, LL.D., D.Sc., and in part, from notes by W. A. E. Ussher, F.G.S. pp. 102, 2 plates, 17 illustrations. Price 2*s*. 3*d*.

The Geology of the Lizard and Meneage. (Explanation of Sheet 359.) By J. S. Flett, M.A., and J. B. Hill, R.N. pp. 280, 15 plates, 10 illustrations. Price 5*s*.

(C.) SCOTLAND.

I.—MAPS.

(*a*.) *Four miles to One-inch Map.*

(Colour-printed.)

Sheet 15, Fife, the Lothians, Berwickshire, &c., price 2*s*. 6*d*.

(*b*.) *One-inch Maps.*

(Colour-printed.)

Sheet 93, Solid and Drift Geology, price 2*s*. 6*d*.

(*c*.) *Six-inch Maps of Mining Districts.*

Dumbarton.—23 SE.; 25 NE.
Lanark.—1 SW.; 10 NE.
Linlithgow.—1 NW.; 1 SW.
Stirling.—29 SE.; 34 NE.

(*d*.) *Six-inch Reference Maps.*

The following copies of six-inch Maps have been completed and deposited in the office for reference:—

Fife.—32 NE., SE.; 33 NW., NE., SW., SE.; 38 NW., NE., SW., SE.
Lanark.—43 NW., NE., SW., SE.; 44 NW., SW.; 47 NW., NE., SW., SE.; 48 NW., SW.
Linlithgow.—5 NW., NE.
Sutherland.—10, 16, 17, 25, 60, 69, 70, 81, 83, 91, 99A.
Ross, 1B, 1C, 2, 2A (and 1A), 3, 5, 5A (and 2B), 7, 9, 13, 14, 33, 45, 46, 47, 58, 59, 70, 71, 85, 91, 95.

II.—MEMOIRS.

The Oil-Shales of the Lothians. Part I. The Geology of the Oil-Shale Fields. By R. G. Carruthers, based on the work of H. M. Cadell and J. S. Grant Wilson. Part II. Methods of working the Oil-Shales. By W. Caldwell. Part III. The Chemistry of the Oil-Shales. By D. R. Steuart, F.I.C. Second Edition. With colour-printed map, sections and a Plate of Fossils. Price 2*s*. 6*d*.

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The Geology of the Districts of Braemar, Ballater, and Glen Clova. (Explanation of Sheet 65.) By George Barrow, F.G.S., and E. H. Cunningham Craig, B.A., F.G.S., with contributions by L. W. Hinxman, B.A., F.R.S.E. 138 pp., 7 plates. Price 2*s.* 6*d.*

The Geology of Ben Wyvis, Carn Chuinneag, Inchbae, and the surrounding country, including Garve, Evanton, Alness and Kincardine. (Explanation of Sheet 93.) By B. N. Peach, LL.D., F.R.S.; the late W. Gunn; C. T. Clough, M.A.; L. W. Hinxman, B.A., F.R.S.E.; C. B. Crampton, M.B., C.M.; and E. M. Anderson, M.A., B.Sc., with Petrological Contributions by J. S. Flett, M.A., D.Sc. 189 pp., 12 plates; 16 text-figures. Price 4*s.*

The British Carboniferous Trepostomata. By G. W. Lee, D.Sc. 61 pp., 3 plates. Price 3*s.*

Guide to the Collections of the Geological Survey illustrative of Scottish Geology, in the Royal Scottish Museum, Edinburgh. 6th Edition. 32 pp. Price 1*d.*

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APPENDIX I.

On some Palæolithic Gravels near Swanscombe, Kent.

By Reginald Smith and Henry Dewey.

The gravels of the Swanscombe neighbourhood have long been known to contain palæolithic implements in association with bones

Fig. 4.—Drawing from photograph shewing section at Barnfield Pit. Overhanging scale is divided by cards into spaces one foot long.

and teeth of extinct mammalia, and in consequence have formed the subject of several contributions to geological literature.

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Although these papers describe the remains, they do not state the exact position of the several finds. This is mainly due to the fact that the implements were purchased from the workmen who only concerned themselves with getting the implements for sale, without troubling to notice their relative positions in the pit. Recent investigation in the valley of the Somme had shown that similar kinds of implements occurred in a definite sequence in the sediments of the river. Hence it was desirable to ascertain if such a sequence existed among the deposits of the Thames, and corresponded with an evolution of form of implement: also to compare results with those of the French investigators.

Early in the year the Associated Portland Cement Manufacturers advised us that they were about to remove the gravels from the Chalk in the pit near Swanscombe where most of the implements had been found, and kindly offered us facilities for a thorough examination of the pit. Our thanks are due to the Company for their courteous invitation and assistance in carrying on the investigation. Arrangements were made for a joint examination of the site by the British Museum and the Geological Survey, and the authors, having been deputed to supervise the excavation, spent about three weeks during the spring upon the work. We employed two gangs of men, each gang being supervised by one of us, so that every spade-full of material was examined, and the chance of implements escaping notice reduced to a minimum. Moreover, as no work was done during our absence, it is unlikely that implements were abstracted without our knowledge. The pit in question is called by the Company "Barnfield Pit." It lies about half a mile north-west of Swanscombe Church and is close to the well-known Galley Hill. The top of the Thanet Sand here is some 90 feet above Ordnance Datum and the gravels in consequence are usually described as the 100 feet terrace.

The following sequence (seen in fig. 4) was found to occur over the whole pit:—

	Soil.
4 ft. 6 in.	Irregular pockets and pipes of gravel in stiff clay (the Upper Gravel). Loam (the Upper Loam).
8 ft. to 18 ft.	Gravel and current-bedded sand (the Middle Gravel).
2 ft. to 4 ft.	Loam and Marl (the Lower Loam).
5 ft. to 6 ft.	Gravel (the Lower Gravel).
0 to 15 ft.	Thanet Sand.
1 ft.	Green-coated flints or 'bull-head.'
	Chalk.

On the northern side of the pit the gravel overlaps the Thanet Sand and lies directly on the Chalk. This overlap is due to the general southerly dip of the Chalk and Thanet Sand.

The *Lower Gravel* is nearly uniform in thickness, ranging from five to six feet. It is divisible into three bands, respectively reddish-brown (resting on Thanet Sand), white and pale yellow in colour. At the junction of the Thanet Sand and gravel the largest flints are found. In composition the gravel is constant, flints from the Chalk and pebbles from the Tertiary beds being the main constituents. Green-coated flints, quartzites of

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various colours and texture, vein-quartz and sarsen stones add about four per cent. to the gravel, while chert from the Lower Greensand is of frequent occurrence and often of large size. All the stones lie in coarse yellow sand.

We found that flint-flakes were large and numerous but ordinary implements entirely wanting. We obtained, however, some palæoliths of very early type in the form of roughly cylindrical pieces of flint chipped at one end into a point or a chisel-edge. They are comparable with the Belgian type named after Strépy in Dr. Rutot's system. Remains of mammalia were common but very tender and friable. One tusk of *Elephas antiquus* measured 6½ feet in length; it was photographed but broke in pieces when it was being removed. Close to it a tooth of *Elephas primigenius* (identified by Mr. Allen) was found by one of the workmen. It is now in the Museum of Practical Geology. The workmen stated that bones and teeth occur commonly in this gravel but are not found in the overlying beds, and our investigations confirmed their observations.

The *Lower Loam*.—Next follows two to four feet of light loam. It is fine-grained, purplish brown in colour, speckled with black spots of manganese dioxide, but locally becomes more marly, light-buff in colour and more friable and laminated. The sandy marl consists mostly of carbonate of lime in the form of broken shells and pellets of chalk, with subordinate grains of sand, and is penetrated by tubular hollows due to decayed rootlets and stems of plants. It contains many shells which are fragile and difficult to extract perfect. Many species, however, are identifiable and we are indebted to Mr. C. N. Bromehead for the following identifications:—

Hyalinia nitida (*Müll.*).
Helix (Tachea) nemoralis *Linn.*
,, (Hygromia) hispida *Linn.*
Succinea, sp. (? oblonga *Drap.*).
Cochlicopa lubrica (*Müll.*).
Bithynia tentaculata (*Linn.*).
Sphaerium corneum (*Linn.*).
Unio or Anodon (fragments).

No implements were discovered in this loam.

The *Middle Gravel*.—Succeeding the loam is a variable thickness of gravels and sand. These are strongly current-bedded, so that gravel and sand laterally replace each other. They average thirteen feet in thickness but vary from eight to eighteen feet. Flint is the main constituent of the gravel, both angular fragments derived directly from the Chalk and water-worn pebbles from Tertiary beds. In addition are some pebbles of vein-quartz, quartzite and other foreign pebbles, but we were unable to find much chert from the Lower Greensand, the Middle Gravels differing from the Lower in this respect and in containing decidedly smaller stones.

Palæolithic implements were numerous but mostly of the ordinary 'pear-shape' and of rather rough workmanship. Those from the lower beds were of Early Chelles type; the upper parts

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yielding more advanced forms, with one or two ovates of St. Acheul character. It is not improbable, therefore that the Middle Gravel represents the whole of the Chelles period and the transition to St. Acheul.

The Upper Loam is about four feet thick. It is missing at the northern end of the pit owing to erosion which has there exposed the underlying gravel. It is described by the workmen as 'puggy-stuff' and is reputed by them to contain white patinated ovates.

The Upper Gravel occurs in irregular pockets in the loam and washes down the pit face giving this member of the Series an appearance of greater thickness than it possesses in reality. It may not be a true river deposit but the result of the washing of material down the slope. Several flakes and one good implement were found in it, but further evidence is required as to the horizon.

A fuller description of the results of the work will be published shortly dealing with the general problems arising from the evidence as a whole. The experiment has been successful in tracing to their respective horizons the earliest types of the 100 feet terrace palæoliths, and in showing that they conform to the order of evolution as established in France.

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APPENDIX II.

The Water Supply of Hampshire.

Erratum.

It has been ascertained that the analysis published under the heading of "The Mount, Fareham," on page 234 of the Geological Survey Memoir on "The Water Supply of Hampshire," is not an analysis of the water from the well at that place. The analysis which should have been given under the above heading is as follows:—

Fareham.

The Mount.

By F. W. F. Arnaud, F.I.C., 15th October, 1906

Parts per 100,000.

Total solid residue	32·5
Chlorine	2·5
Salt	4·12
Free Ammonia	0·0005
Albuminoid Ammonia	0·003
Nitrogen as Nitrates	0·17
Oxygen absorbed (4 hours) ...	0·029
Nitrites	Absent
Total hardness	16·0
Permanent hardness	6·0

Remarks.- Clear and colourless. The above figures show the water to be of good organic quality.

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APPENDIX III.

Boring at the East Anglian Ice Co.'s Works, Lowestoft.

By A. Strahan, Sc.D., F.R.S.

This boring was commenced in 1912, and a section of the strata down to the Chalk was communicated by Messrs. Tilley. This account, supplemented by a large number of notes by Mr. Whitaker on specimens examined by him, was published in 'The Water Supply of Suffolk' (*Mem. Geol. Survey*), 1906, p. 88.

In 1908-11 the boring was carried down to a depth of 1832 feet by Mr. Thomas Mills, to whom we are indebted, through the kind offices of Mr. F. W. Harmer, F.G.S., for the additional information.

The boring is situated on the south side of the Inner Harbour, 500 yards east of Colville House, at a height of 12 feet above Ordnance Datum. The following section is made up, so far as regards the beds above the Chalk, of an abstract of the section already published, and so far as regards the Chalk and the beds below it, of an account furnished by Mr. Mills. The notes in square brackets added to Mr. Mills' account are founded in part on an examination of specimens supplied by him.

Section of boring.

	Thickness. Feet	Depth. Feet.
Drift	69½	69½
Chillesford Clay (supposed)	4½	74
Crag	166	240
London Clay	160	400
Reading Beds	75	475
Chalk, with flint-stones at 661 and 747 feet; fine black flint at 1,320 feet; clay at 1,380 feet; traces of blue clay at 1,416 feet; brown pasty chalk at 1,424 feet; indications of flint and green clay at 1,481 feet; greenish clay at 1,485 feet; indications of black and white flint, green chalk, chalky rock at 1,490 feet; chalk mixed with blue clay and small stones at 1,500 feet; brown chalk and black flints at 1,511 feet; clay mixed with chalk at 1,519 feet; tough blue clay and chalk at 1,525 feet...	1,050 [1,055]	1,530
Upper Greensand; green clay and chalk with black sand at 1,538 feet	11	1,541
Gault; clay and black sand with pyrites at 1,544 feet	45	1,586
Lower Greensand; with two feet of greensand and four feet of sandstone from 1,586 to 1,592 feet [possibly base of Gault]; hard sandy clay with sand and stones at 1,596 feet	41	1,627
Rock [pale mudstones, highly micaceous in parts; Cambrian or Ordovician] to ...	205	1,832

As a source of good water the boring is a failure. According to the account published in the 'Water Supply of Suffolk,' about 3000 gallons an hour were pumped for four days at a depth of 680 feet, when the water turned salt. Eventually a number of

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5 lb. charges of gun cotton were exploded by Mr. Mills between the depths of 1627 and 1832 feet, the flow of water which had been 1500 gallons per hour being thereby increased to 5400 gallons an hour. Mr. Mills writes that "the pressure of water at the surface is 22 lbs. to the square inch, and the water rises about 60 feet above sea-level, but the quality was medicinal." An analysis by the Chemical Research Association gives the following results, expressed in parts per 100,000:—

Calcium carbonate	10·4
Calcium sulphate	203·0
Magnesium sulphate...	77·9
Sodium sulphate	56·8
Sodium chloride	519·6
Potassium chloride	10·3
Ferrous carbonate	0·2
Total mineral solids	878·2
Water of hydration, &c.	3·8
Total solids	882·0

Specimens from depths below 1586 feet were presented to this Institution by Mr. Mills. As a result of the explosions a cavity had been formed into which nodules and sand from the Lower Greensand had rolled down and had been mixed up with the debris of the palæozoic rocks. Many tons of sand were carried away in the water that was pumped up, but much was saved.

The samples of Lower Greensand, after the palæozoic debris have been picked out, consist of sharp quartzose sand, some very coarse in grain. The lowest bed is a coarse grit, and contains well-rounded quartz-pebbles up to a third of an inch in length. In it there are also many dark phosphatic and pyritous concretions, often cylindrical and upwards of 2 inches in length, while some are spherical; they consist of quartz-sand firmly cemented. A few fragments of belemnites and ammonites occur among them, and among the pebbles there is an occasional specimen of lydian-stone and of mudstone resembling the underlying palæozoic rock.

The palæozoic rock, which was produced in small fragments only, consists for the most part of darkish or pale hard mudstone, micaceous in parts, not obviously cleaved. It has yielded brachiopods of the genera *Lingula* and *Orbiculoidea*. These are probably new species, but are too fragmentary for description. Dr. Matley, to whom they have been submitted, considers their age to be Cambrian or Ordovician, probably the former.

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APPENDIX IV.

Boring at the Bird-in-Hand Inn, Henlow Station, Bedfordshire.

By A. Strahan, Sc.D., F.R.S.

An account of this boring has been published by Mr. W. Hill in the *Proc. Geol. Assoc.*, vol. XXIII. (1912), p. 223. The following additional details have been derived from an examination of the specimens and from information provided by Messrs. Isler & Co.

The boring is situated at about 180 feet above Ordnance Datum, and close to the estimated position of the junction of the Chalk and Gault below boulder-clay. A well at Arlesey, about 2 miles to the N.E. started in the top of the Gault, reached its base at 213 feet and was carried for 4 feet into Lower Greensand. Near Henlow the base of the Chalk runs at about 230 feet above O.D., and the base of the Gault might have been expected therefore at about 17 feet above O.D., that is at a depth of 163 feet from the surface. The boring was taken to a depth of 456 feet, and was in boulder-clay as shewn by Mr. Hill to a depth of 354 feet, a specimen of clay with chalk-flints from that depth having been submitted for examination. The remainder of the section is described by Messrs. Isler & Co. as follows:—

	Thickness.		Depth.	
	Ft.	Ins.	Ft.	Ins.
Sandy clay	22	0	376	0
Sand-rock (brown)	11	6	387	6
White rock (?)	35	6	423	0
Reddish rock or clay (?) ...	28	0	451	0
Red clay (sandy)...	5	0	456	0

Supply—250 gallons per hour.

The "sand-rock (brown)" proved on examination to be a coarse and gravelly incoherent grit; the "white rock (?)" proved to be a fine-grained white silt, setting hard on drying. Neither of them presented any resemblance to Lower Greensand and both are likely to be of pleistocene age. The "reddish rock or clay (?)" and "red clay (sandy)" are red mottled marls not distinguishable from Keuper Marl.

If we allow 50 feet for the thickness of the Lower Greensand in the neighbourhood, and 250 for that part of the Oxford Clay which survived erosion before the Lower Greensand was deposited, we arrive at an estimate that the base of the Oxford Clay might have been expected in the boring at a depth of 463 feet from the surface. It is certain that nothing resembling Oxford Clay was met with. The age of the mottled marls therefore remains uncertain.

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APPENDIX V.

Batsford (or Lower Lemington) Boring, near Moreton-in-Marsh.

By A. Strahan, Sc.D., F.R.S.

This boring was carried out in the years 1901-04 by the Batsford and Todenham Coal Syndicate. For permission to examine the cores and for much information respecting it we are indebted to Mr. W. P. Evans, Managing Director, on whose initiative the exploration was made. The work was carried out by Mr. A. H. Staley, Engineer to the Syndicate. The boring was visited in 1902 by Mr. H. B. Woodward and Mr. E. T. Newton, and subsequently a collection of fossils from the cores was made by Mr. J. Pringle. The following section is made up from an abstract of the journal supplied by Mr. Evans, with a classification of the strata founded on the observations of Messrs. Woodward and Newton. The site is 350 yards W. 22° N. of Lower Lemington Church, in the New Series one-inch Map 217, at a height of about 380 feet above O.D.

Batsford Boring.

		Thickness.	Depth.
		Ft.	Ft.
Lower Lias	Shales with limestones	418	418
Rhætic	White Lias at 418 feet and 425½ feet; grey shaly marl, greenish shale and brown clay, 427 feet to 448¾ feet: dark marl and black shale with *Pteria contorta*, 453 feet to 466½ feet.		
	Limestone at 461¾ feet	48½	466½
Keuper	Tea-green marl with limestone at 481 feet	15	481½
	Red and green marl	8	489½
	Red and blue marl with bands of gypsum at 620 feet, 637 feet, 657 feet	458	947½
	Sandstone	74	1,021½
Upper Coal Measures.	Grey shale and sandstone, with ostracod-limestone at 1,024 feet, coal-smuts at 1,050 feet and 1,126 feet, plant-remains, &c. ...	133	1,154½
	Sandstone with streaks &c. of coal, resembling Pennant; some bands of conglomerate	226½	1,381
	Grey and red shale and red marl ...	61½	1,442½
	Sandstone and conglomerate with "coal-veins" and "coal-joints" ...	103½	1,546
Silurian	Grey shale with sandstone and limestone. Fossils	154½	1.700½

The dip of the Coal Measures was about 6° or 7° and that of the Silurian rocks, 20° to 25°, but the exact position of the junction is not determinable from the record further than that it lies below 1527 feet, and above 1590 feet where the first identifiable Silurian fossils were obtained.

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Fossils.

The following fossils were collected from the cores and have been identified in the Palæontological Department of the Survey, or, as regards the plants, by Dr. Kidston.

Rhaetic:—*Lima sp.*, *Myophoria sp.*, *Pecten valoniensis* Defr., *Protocardia rhaetica* (Merian), *Pteria contorta* (Portl.), *P. sp.*, smooth. At 466 feet the cores yielded *Acrodus minimus* Ag., *Gyrolepis alberti* Ag., *Hybodus minor* Ag., *Saurichthys acuminatus* Ag. Presumably this represented the 'bone-bed.'

Coal Measures:—In the following lists the depths in feet at which the specimens occurred are given in brackets.

Neuropteris flexuosa *Sternb.* (1,091).
,, ovata *Hoffm.* (1,091).
,, rarinervis *Bunb.* (1,089½–1,092).
,, scheuchzeri *Hoffm.* (1,116, 1,123, 1,126).
Pecopteris miltoni (*Artis*) (1,091, 1,124).
,, sp. (1,123, 1,126).
Sphenopteris sp. (1,033).
Calamites *cf.* suckowi *Brongn.* (1,033).
Asterophyllites equisetiformis *Schloth.* (1,091).
Cordaites principalis (*Germar*) (1,089½–1,092, 1,520).
Pinnularia capillacea *L. and H.* (1,123).
Stigmaria ficoides *Sternb.* (1,127, 1,142).

There occurred also *Anthracomya* (?) at 1,156 feet, Ostracoda at 1,022–1,024 and 1,156 feet. Plant-remains (indeterminable) were obtained at 1,313½, 1,427, 1,432, 1,506 feet.

Silurian:—*Serpulites* (1,639), *Atrypa marginalis* (Dalm.) (1,599, 1,682), *A.* cf. *reticularis* Linn. (1,590, 1,592, 1,612, 1,639), *A. sp.* (1,653), *Orthis sp.* (1,682), "*Rhynchonella*" *stricklandi* (J. de C. Sow.) (1,682½), *Tentaculites* cf. *tenuis* J. de C. Sow. (1,653), *T. sp.* (1,639, 1,653), *Phacops* ? (1,653).

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APPENDIX VI.

The Copper Lodes of Inveryne and Kilfinan, Argyllshire.

By C. T. Clough, M.A., F.G.S.

It has long been known that the Highland schists on the west side of Loch Fine are crossed by veins carrying metallic ores to a certain extent, and some of these veins have been worked on a small scale: the most common ores are perhaps those of copper and lead, and in certain districts, for instance near Loch Errol, the schists are widely stained with copper compounds.[1]

Until lately it has been the general impression that on the east side of Loch Fine metallic ores are less abundant than on the west, though it was known that on the east also certain outcrops of schist contain diffused copper ore, for instance half a mile north of the Clachan of Glendaruel.[2] Quite recently it has been discovered by the promoters and officials of the Otter Copper Company, Ltd., that certain bands of schist on the east side are generally impregnated with copper ores for a distance of at least two or three miles along the strike, and in one of these bands a mass of ore of considerable economic value and scientific interest has been deposited. The following account has been compiled with the object of recording the leading facts at present known about these bands. This could not have been done without the help of the Company's officials, and it is a pleasing duty to express our thanks for their kind assistance.

The rock that carries the bands just referred to is the well known Loch Tay Limestone, a bed which has been traced in a nearly NNE., direction across a great breadth of the Highlands, from the neighbourhood of Campbeltown to some distance beyond Pitlochry. In Argyllshire this limestone is often mixed inseparably with some calcareous quartz-schist and thin seams of leaden-coloured phyllite, and the average thickness including these is often about 30 ft. though in certain localities the apparent thickness is much increased by folding. This limestone is exposed on the north side of Auchalick Bay, about four miles slightly north of west of Tighnabruaich (one-inch map 29), and extends thence past the hamlet of Kilfinan into the upper part of Glendaruel. It is displaced by various lines of fault, and the main crop is frequently accompanied by thinner subparallel crops of limestone, some of which perhaps belong to independent beds.

In the limestone at Auchalick Bay and for half a mile NNE., no indications of copper have yet been detected, but near a farm house called Inveryne (six-inch map Argyll 181 SE.), about a mile from the bay, it is richly impregnated, close to the surface with the green carbonate, and, at a slightly greater depth, with this ore and a grey sulphide, consisting chiefly of copper glance (chalcocite). At Inveryne the limestone is divided into three

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[1] 'The Geology of Knapdale, Jura and North Kintyre' (*Mem. Geol. Surv.*), 1911, p. 139.

[2] 'The Geology of Cowal' (*Mem. Geol. Surv.*), 1897, p. 81.

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bands separated from one another by bands of epidiorite or hornblende-schist, usually from 20 to 50 yds. in breadth, which are believed to represent intrusive sills. The limestone usually dips WNW., at 30° or 40°, but is frequently affected by small folds. The hornblende-schist in this locality carries very little ore, but one or two thin quartz veins bearing a little chalcocite have been detected in it by the Company's servants.

The lodes are not well defined fissure veins nor impregnated fault breccias, but are merely those portions of the limestone which are well charged with diffused ore. They are not always so broad as the limestone band with which they run, and it seems probable that they vary in thickness rather rapidly as they are traced along the strike.

At Inveryne and also in some other localities to be soon referred to, the indications of copper at the surface before any exploring work had been done are stated to have been extremely slight. They consisted merely of small bits of greenish weathered limestone which had been dug out by the rabbits, or else perchance of a rabbit bone also stained green. But in the exploring trenches and inclines spots and streaks of the green carbonate, lying either along the bedding or on cross joints, are seen in abundance throughout a considerable mass of rock, and at depths of 6 or 7 ft.,[1] the green ore begins to be accompanied by the grey sulphide both in small scattered specks and streaks, rarely more than half an inch thick, which sometimes cross the bedding.

The No. 2 lode (the middle lode) at Inveryne is about 11 ft. thick, measured at right angles to the dip, but there are indications of ore in the roof also. Mr. J. S. Taylor, the Managing Director of the Company, states that one sample weighing about 5 tons was taken from this lode without any special selection and yielded 8·2 p.c. of copper, but that the yield did not continue so good as this for all the period of working.

North-north-east of the lodes at Inveryne other outcrops of limestone have been found to carry copper in the following localities: close to Drum Farm; 230 yds. NNE., of Drum Farm; 660 yds. slightly north of west of Acharosson; 630 yds. slightly west of south of Tigh-an-rathaid. But all these and the Inveryne lodes are for the present subordinate in interest to another lode which is now being opened up by a mine about a third of a mile ENE., of Kilfinan Church, and has been called "The Murder Lode." The spot at which it was found is in a field and was selected for exploration because it was known that no grass or crop could be got to grow there even though heavily manured. Local tradition said a curse lay on the spot because it had been the scene of a bloody fight to death between two women, but the company's officials shrewdly suspected that the true cause of the barrenness might be the presence of poisonous copper salts or of free sulphuric acid permeating upwards. They therefore started to mine below the barren spot, and soon came to a vertical vein of copper carbonate about 2 ins. thick, which crossed the bedding of the limestone and had a nearly north-and-south strike. This vein

[1] There is no appreciable cover of drift.

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was followed for about 40 ft. towards the north and is stated to have then suddenly expanded into a solid mass of grey sulphide one or two feet thick.[1] This mass had at the time of our visit last December been followed to the north for 12 or 14 yds. further and been found to be even thicker in places than where first encountered, but it had not then been proved to a greater depth than 12 or 13 ft. At that time at the northern end of the workings the rib of sulphide seemed to have a NNW. strike. In the upper part of an underground road we saw a mass of grey sulphide which was about 2 ft. wide: its south-west side was vertical and was bordered by a thin streak of reddish clay with diagonal slickensides, and on the other side of this clay the bedding of the limestone was quite distinct and dipped WNW. about 40°. In the lower part of the same road the ore widened out in a 'float' along the bedding of the limestone for a distance from the vertical side of at least 2 or 3 ft. and to a depth across the bedding of at least 2 ft. Some blocks of the massive sulphide lying on the bing showed thin parallel streaks of limestone every here and there, and indications of banding parallel to these streaks. Such phenomena strongly suggest that the masses of ore have been in part formed by a metasomatic or replacement process, the copper sulphide taking the place of limestone. Vein quartz occasionally occurs with the chalcocite, and chalybite is also sometimes found. It is too soon to speak with confidence, but the fact that the main body of ore appeared to be a sudden expansion of a vertical vein, together with the vertical position of the side of the sulphide mass in the upper part of the road, suggests that the sulphide here was first introduced along a fissure and afterwards spread out on a large scale into the limestone at the sides. It is quite possible that even the vertical rib is of secondary origin, but of this we have as yet no evidence.

The whole of the limestone near the mass of solid sulphide is also strongly charged with spots and streaks of copper ore, partly the grey sulphide, but chiefly the green carbonate. The streaks usually run along the bedding and are often nearly half an inch thick. In some blocks of calcareous quartz-schist associated with the limestone, specks of grey sulphide are abundant near the inside, but are all replaced by green carbonate near the outside. Thin laminae of grey sulphide that follow the folds of the rock for considerable distances are also seen to be bordered on either side by skins of green carbonate. There can be no doubt, indeed, that all the green carbonate has been formed from the grey sulphide under the influence of water carrying carbonic acid or carbonate of lime in solution. Besides the streaks that occur along bedding or foliation planes others are frequently found on cross joints.

A deep blue carbonate, azurite, is also tolerably common along the cross joints. A coating of bright red ore, apparently the red oxide of copper (Cu_2O), was also noticed on a joint crossing a solid mass of grey sulphide. Mr. J. S. Taylor states that he has

[1] Mr. Taylor states that the total width of the lode near here was from 12 to 14 feet, slightly more than half of it being carbonate and the rest sulphide (glance).

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seen several small pieces of native copper, one about the size of a match-head, but we do not know how they occurred. We are not aware that copper pyrites has anywhere been observed.

A crag of hornblende-schist 100 yds. WSW., of the mine shows a slight stain of green carbonate on certain of the foliation planes. This crag is bounded on the WSW. side by a limestone which we think is probably connected by folds with the limestone in the mine. Mr. Taylor tells us that about a mile NNE. of the mine there is a considerable show of green carbonate in a hornblende-schist and also in an adjacent mica-schist.

A number of vertical veins of barytes, rarely more than an inch wide, strike north-west across the lode near Acharosson, but they do not appear to carry any copper ore, though joints parallel to them are often stained green. A thin nearly east-and-west whin dyke, of tholeiitic character and probably of Permo-Carboniferous age, also cuts the above lode in a locality almost due west of Acharosson. The southern margin of the dyke has been crushed for a breadth of a few inches, and is stained in places with green carbonate, but this ore may very likely have been introduced at a comparatively late period. The uncrushed portion of the dyke does not seem to carry any copper ore.

It is not certain that any of the ore has been subjected to mechanical deformation of the kind that might have been expected if it had been in existence prior to the development of the foliation of the schists. Both sulphide and carbonate streaks often keep along the foliation planes of the rock even when these are closely wrinkled, but it is conceivable that they may both have been deposited along pre-existing planes. As far as can be made out by microscopic examination the streaks of sulphide that occur along the foliation do not differ in structure from those that cross these planes.

It may be mentioned that in regard to the evidence respecting the age of the lodes in the area west of Loch Fine, Mr. J. B. Hill says they "may be connected with the granitic intrusions of the Lower Old Red Sandstone or early Silurian period, but the evidence on this point is far from conclusive."[1]

A consideration of all the facts at present known suggests that other large bodies of solid sulphide, like that in the Murder Lode, may also exist as yet undiscovered in the Inveryne, Tigh-an-rathaid and other lodes. There may be considerable difficulty in finding these other bodies, but it is hoped that the experience gained in working the Murder Lode will be of service in conducting the searches elsewhere.

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[1] 'The Geology of Knapdale, Jura and North Kintyre' (*Mem. Geol. Surv.*), 1911, p. 140.

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Great Britain

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OF THE

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OF

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AND THE

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SUMMARY OF PROGRESS

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FOR 1913.

I.—*INTRODUCTION.*

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

Soon after the close of the year 1913 Dr. Teall retired from the Directorship of the Geological Survey. The work therefore of which the progress is described in the following pages was carried out under his direction. It has been concentrated so far as regards England and Wales in the three districts which were instituted in 1910, namely the Denbighshire District (including parts of adjacent Counties), the Warwickshire and Staffordshire District, and the London and South-eastern District.

In the Denbighshire District, the surveying has been carried southwards into Shropshire. Some further colliery information remains to be gathered in Flintshire, but the part of Cheshire included in the District has been completed.

In the Warwickshire and Staffordshire District the surveying of the visible Warwickshire Coalfield has been nearly completed, and that of the concealed coalfield has been carried nearly to the southern margin of Sheet 169. Progress has been made in the surveying of the drift-covered Triassic plain on both sides of that coalfield.

In the London and South-eastern District the Upper Chalk and Lower London Tertiary Beds have been under examination, and the Pleistocene deposits, which occupy a large part of the area north of the Thames, have received close attention.

In Scotland good progress has been made in the mapping of the Isle of Mull. In Raasay and Skye an oil-shale has been recognised in the base of the Great Oolite Estuarine Series, and the revision of the coalfields of South Lanarkshire and North Ayrshire is advancing at a satisfactory rate.

The results of the work on the various geological formations may be briefly summarised as follows:—

Crystalline Schists and their associated Igneous Rocks.

In Scotland work has been continued on the original survey of the Highlands on the six inch scale principally in the counties

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of Sutherland, Ross and Argyll. The metamorphic schists of Central Sutherlandshire comprise gneisses of Lewisian type and granulites and schists which belong to the Moine Series. The district has been flooded by intrusions of granite which have formed remarkable intrusion-complexes with the schists. The distinctions between these rocks are often difficult to define and the boundary-lines are obscured by the extensive deposits of peat which characterise the interior of Sutherlandshire.

In the Island of Kerrera, near Oban, the black slates and limestone of the Easdale series form a platform on which the Old Red Sandstone conglomerates rest with a marked unconformability.

Pre-Cambrian and Cambrian.

The surveying of the rocks which emerge from beneath the Warwickshire Coal Measures near Nuneaton has given results which are in general agreement with the old one-inch map, but has shown the necessity of some modification in the mapping of the intrusive sheets of diorite.

Ordovician.

In disentangling the structure of these rocks in Cyrn-y-brain, Mynydd Cricor and on the south side of the Llangollen syncline, the Corwen-Glyn Grit has proved a valuable stratigraphical guide. This grit has been described in various disconnected occurrences under the names of Corwen Grit, Glyn Grit, etc., but has now been proved to have been continuous round the syncline. It appears to be at least as closely associated with the Ashgillian as with the Llandovery beds above, both palæontologically and lithologically.

A group of strata lying below the Cwm Clwyd Ash, which was referred to in the 'Summary of Progress' for 1912, p. 7, has now come under examination. A few fossils, including *Trinucleus*, have been obtained from it, and beneath it are mudstones in which have been noted some thin beds of ash, some black shales with lapilli and a vesicular lava. An ophitic dolerite, worked under the name of 'Ceiriog Granite,' has been intruded into these beds, along cleavage-planes. These mudstones pass down into the richly fossiliferous Llandilo limestones and ashes exposed in the inliers of the Iwrch and Rhaiadr Valleys.

Silurian.

Llandovery and Tarannon rocks have been examined to the north and south of the Dee. Though the presence of both is proved by the graptolites they are difficult to separate. In the Tarannon beds graptolites have been found at a sufficient number of horizons to render possible a comparison with the typical Tarannon area. The occurrence of purple bands is an interesting feature, which the Tarannon beds of North Wales possess in common with those of South Wales and Westmorland.

In the Wenlock-Ludlow group a persistent and uniform band of slates, belonging to *Cyrtograptus murchisoni* beds, has been

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quarried throughout the district. Above this there follows a great thickness of almost unfossiliferous sandy slates, sandstones and flags, in which must lie the junction between Wenlock and Ludlow.

Old Red Sandstone.

Further evidence of the former extension of the Middle Old Red Sandstone over the Northern Highlands has been obtained by the discovery of a considerable area of conglomerate and red grits two miles south of Loch Gaineamhach in Sutherlandshire.

In Kerrera representatives of the 'Lorne traps' have a considerable development and are accompanied by sandstones and conglomerates that are known to contain Lower Old Red Sandstone fossils. The lavas are mostly andesites similar to those of the mainland of Argyllshire. In north-western Ayrshire near Largs and West Kilbride the new base-line that has been adopted for the Lower Carboniferous is drawn above a series of reddish sandstones that are relegated to the Upper Old Red Sandstone. This series contains a well-marked 'cornstone' horizon.

Carboniferous Rocks.

In Warwickshire the mapping of the Etruria, Halesowen and Keele groups has been continued south of Nuneaton. A thin band of *Spirorbis*-limestone, known as the Index Bed, which occurs about 150 feet below the top of the Halesowen group, has been traced as far as Bedworth and has been recognised in an inlier at Arley.

Above the Halesowen group there have been found to be upwards of 2,500 feet of sandstones with conglomerates and marls. No unconformity has been detected in them, and there is as yet no palæontological evidence to show whether any part of them can be assigned to the Permian.

In Denbighshire the examination of the Carboniferous Limestone escarpment south of Llangollen has been completed. In Flintshire some sandstones near Hawarden, which have hitherto been regard as Lower Coal Measures, have now been proved to be Millstone Grit by the fact that they are overlain by fossiliferous Holywell Shales. The well-known fire-clays of Buckley have received particular attention. They lie above the Hollin Rock but below the horizon of the Ruabon Marl, and perhaps indicate that Upper Coal Measure conditions prevailed locally in Flintshire at an earlier date than they appeared in Denbighshire. Some further evidence has been gathered respecting the unconformity suspected to exist at the base of the Upper Coal Measures at Flint.

In Scotland revision of the original survey of the Carboniferous districts has proceeded in North Ayrshire, the Paisley District, and around Hamilton in Lanarkshire. The occurrence of an unconformability in the Millstone Grit of the Avon Gorge has been amply confirmed by the field-work, and evidence has been obtained in Ayrshire of a similar break in the sequence at the same or approximately the same horizon. It has proved possible to correlate the results of the geological mapping of the

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Carboniferous Limestone areas in Lanarkshire, Renfrewshire and Ayrshire, and to interpret the sequence in the two principal western coal-fields in terms of one another, so far as the beds below the Johnstone clay-band are concerned.

Permian.

The possibility that some part of the red sandstones, conglomerates and marls, which lie above the representative of the Keele group in Warwickshire, may be of Permian age, has already been mentioned.

In Scotland, throughout the Ayrshire coal-field, a large number of volcanic necks are known that have cut through the Coal Measures. They have been regarded as of Permian or New Red age, and this has been confirmed during 1913 by the discovery in them of small fragments and large blocks of the round-grained desert-sandstones that bear all the characters of the red sandstones (Permian?) of Ballochmyle.

Trias.

In Cheshire the surveying of the peninsula of Wirral has now been completed. The Pebble Beds are the lowest rocks seen in the northern part. They form Hilbre Island and a reef running south-eastwards from it. The rocks known as Caldy Blacks and Seldom Seen Rocks are with less certainty referred to the same sub-division. A commencement has been made on the deeply drift-covered Triassic area near Oswestry.

The Keuper Basement Beds are generally red on the western side of Wirral but buff on the eastern side. An equally marked change in colour is observable between Helsby and Manley. The Waterstones have yielded carbonised fragments of an equisetalean plant.

In Warwickshire the Lower Keuper Sandstone consists of thin red and white sandstones interbedded with red marls. It corresponds, therefore, in character with the Waterstones rather than the Keuper Basement Beds of Cheshire. It comes to rest upon the Cambrian rocks near Nuneaton and then assumes a conglomeratic character. The Arden Sandstone group described by Dr. Matley as a distinguishable group in the Keuper Marl has been traced for some distance.

Jurassic.

In Scotland small patches of Jurassic rocks, in addition to those previously recorded, have been found in several places underlying the Tertiary lavas of Mull.

It has been decided to make a more detailed investigation of the palæontological zones of the island of Raasay on account of the importance of the iron-ore deposits of that island, and with a view of facilitating the search for this horizon in other parts of Scotland. Fossils are numerous and exceptionally well preserved, and so far as the palæontological study of the material collected has as yet gone it seems likely that the results will prove of exceptional interest. It may also be possible by this means to

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fix the exact stratigraphical position of the ironstone which is not at present established beyond question.

The discovery of an extensive deposit of oil-shale in Raasay and in Skye may have a bearing on the future supplies of oil from Scotland, though the specimens that were collected from the exposed surface of the shale-bed have proved to be by no means rich.

Cretaceous.

In the London District the surveying of the Chalk has been continued on both sides of the Thames. The interesting fauna characteristic of the horizon of *Heteroceras reussianum* has been proved to have had a wide extent.

Tertiary.

The surveying of the Lower London Tertiary Beds has led to investigation of the relations of the developments known respectively as the Thanet Sand, the Woolwich and Reading Beds, the Oldhaven (or Blackheath) Pebble Beds. The Thanet Sand expands eastwards, and is overlain by a group of lenticular sands and clays with occasional pebble-beds which constitute the Woolwich and Reading Beds. Upon these rest thick masses of shingle which are liable to be replaced within a few yards by sands with a few pebbles. These form the Oldhaven or Blackheath Beds, and are followed by London Clay, also pebbly in its lower part. The whole group of sands, clays and pebble-beds are regarded as a single series deposited under rapidly varying conditions.

Further light has been thrown by the mapping on the faults and folds which affect the strata underlying London.

The mapping of the interior of Mull has been continued during 1913, and has yielded some interesting results. A great series of arcuate folds encircles the central intrusive masses. These folds involve the basement-platform of metamorphic and palæozoic rocks and the Tertiary lavas. Formerly they were known to extend round one half of Central Mull, but during 1913 they have been traced for a further distance of ten miles, still following a curved course. The felsite dyke of Loch Bà has also been proved to describe a curve like a shepherd's crook and to turn back on itself towards the interior of the island.

An interesting feature of the year's work in Mull has been the discovery in several places of intrusive masses which vary in composition from granophyre to gabbro, the heavier basic rock occurring at the base of the complex, while the lighter granophyre forms the top. There is a gradual transition from the one type of intrusive rock to the other and the facts, so far as observed, indicate that differentiation has taken place *in situ*.

Pleistocene and Recent.

In Denbighshire and Flintshire the area surveyed includes a part of a great flat near Oswestry which is occupied by a flood-

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gravel of anomalous character, and the origin of which is still under investigation.

In Warwickshire the relationship of the drifts transported respectively by the Eastern (North Sea) Glacier and by the Western (Irish Sea) Glacier has been further investigated. The eastern drift near Hinckley contains abundant flints, many fragments of fossiliferous Jurassic limestone, and some igneous and Carboniferous rocks. The western drift is devoid of flints and mainly composed of Triassic material.

In the London district the deposits of some dry chalk-valleys near Croydon and their connection with the terraces of the Thames have been under consideration. On the north side of the Thames the composition and distribution of the high-level drifts has formed an important part of the work. The predominance of worn or unworn flints, the presence or absence of pebbles derived from the Bunter Beds and the presence of other boulders whose origin may prove to be identifiable, all having much significance.

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II.—FIELD WORK.

(A.) ENGLAND AND WALES.

The geological surveying of the three districts which were commenced in 1910 has been continued, namely:—

1. Denbighshire District under Mr. G. W. Lamplugh.
2. Warwickshire and Staffordshire District under Dr. W. Gibson.
3. London and S.E. District under Mr. G. Barrow.

Several important sections and borings outside the areas now being surveyed have also been examined during the year. These include various borings for coal in Buckinghamshire, Kent and Yorkshire.

1.—Denbighshire District.

G. W. Lamplugh, F.R.S., District Geologist.
C. B. Wedd, B.A.
B. Smith, M.A.
L. J. Wills, M.A.
W. C. Simmons, B.Sc.
W. B. R. King, B.A.
D. A. Wray, B.Sc.
} Geologists.

During the year, the revision of the Flintshire Coalfield and of the Wirral peninsula in New Series Sheets 96 and 108 of the One-inch Map has been completed, while the survey of the Denbighshire Coalfield and of the Older Palæozoic rocks to the west, has been carried southward through Sheet 121 (Wrexham) and over the northern part of Sheet 137 (Oswestry).

Ordovician.

The mapping of the isolated tract of Ordovician rocks forming the rounded mountain-mass of Cyrn-y-brain at the north side of the Llangollen basin was completed by Mr. Wills, who in conjunction with Mr. Smith, also surveyed an area of rocks of the same age south of the Dee between Moel Fferna and Corwen.

Cyrn-y-brain is largely composed of sandy shales or grits with abundant fossils. In the main the structure of the mass is an anticline, on both sides of which an uncleaved grit has been found comparing closely with the Corwen-Glyn grit (see below).

Mr. Smith recorded a similar grit at Mynydd Cricor in the 'Summary' for 1912, p. 6. It thus appears that the Corwen-Glyn grit was once continuous round the Llangollen syncline. For this reason it forms a valuable stratigraphical horizon.

On the south side of the Llangollen syncline, Mr. Wills traced the Ordovician rocks to the west edge of the map (Sheet 121). The 'Glyn Grit' of Messrs. Groom and Lake, that was last year followed from Glyn-Ceiriog as far west as Moel Fferna (see 'Summary of Progress' for 1912, p. 8), has been followed to Corwen into the area mapped by Mr. Smith and proved to be the

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same as the Corwen Grit. This grit was formerly referred to the base of the Llandovery, but it seems likely that Messrs. Groom and Lake are right in thinking the fossils found in the grit at Glyn indicate a closer relation to the Ashgillian (Dolhir Beds). In this connection it may be pointed out that there is probably no unconformity here between the Llandovery and the Ashgillian, for the main grit is heralded in by thin grit-bands in the underlying mudstones and followed by thin grit-bands in the Llandovery Slates. Further, high up in the Dolhir Beds in the neighbourhood of Moel Fferna, *Meristella crassa* (J. de C. Sow.) was found, and it is extremely abundant also at Cyrn-y-brain. As this brachiopod has formerly been recorded only from the Llandovery, its presence along with *Chasmops macroura* (Sjög.) and other Ashgillian forms indicates a palæontological connection also between the Llandovery and Ashgillian groups.

If there is no stratigraphical or palæontological break at the base or summit of the grit its reference either to Ordovician or Silurian becomes quite arbitrary. It seems, however, to associate itself more naturally with the Ordovician, in which a sandy character is more prevalent than in the Llandovery.

In the Oswestry sheet Mr. King has mapped an area in the Ceiriog valley south of that surveyed by Mr. Wills in 1912. The group referred to by Mr. Wills in last year's 'Summary of Progress' (p. 7) as 'Beds below the Cwm Clwyd Ash' extends over the northern part of this area, and a few brachiopods and trilobites, including *Trinucleus*, have been obtained from a grit-band in it. This band might be taken as a convenient base for the group. The underlying beds are mudstones, often with bands of shale or grit; these occupy all the ground to the southward up to and including the Mynydd Tarw ridge. On the summit of this mountain there occurs a bed of pale ash (not noted on the Old-series map) which may prove to be of stratigraphical consequence. The well-known bands of ophitic dolerite of the Ceiriog valley ('Ceiriog Granite') were found to be intrusive along the cleavage.

In the country farther south, mapped by Mr. Smith, to the north of Llanrhaiadr-yn-Mochnant, the rocks of Mynydd Mawr appear to be similar to those of Mynydd Tarw, but they contain some thin bands of ash and ashy shale which attain a fuller development farther westward. The only fossils observed up to the present in this series are a few obscure graptolites. Among the rocks denoting igneous activity the most interesting are some black shales with lapilli and fresh felspar crystals, and a vesicular lava.

These beds pass downward without break into the richly fossiliferous limestones and ashes of Llandilo age which appear at the surface as inliers in the Iwrch and Rhaiadr valleys. Of these the Iwrch or Craig-y-glyn mass, which is much the larger, is bounded on all sides by faults; its base is not exposed except at one point where, close to one of the boundary faults, a small thickness of shale is visible below the lowest ash-bed. Including some shaly calcareous beds at the top of the limestone, the inlier is considerably larger than the old map shows. In the smaller inlier of the Rhaiadr valley, the limestone is much thinner than in the Iwrch inlier.

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In this district the upward limits of the Llandilo division will be difficult to fix, owing to the rarity of fossils, coupled with the faulted character of the ground. South of Llanrhaiadr the boundary might perhaps be drawn at a belt of fossiliferous flags and shales exposed near Ceunant. The Bala division south of the Tanat valley is composed of fossiliferous grits and shales, including a thin band of limestone, mostly dolomitic, which is best exposed in an old quarry at Pen-y-garnedd. The beds in this area are steeply inclined and in places reversed, and a study of the cleavage leads Mr. Smith to conclude that the reversal took place after the cleavage was developed. Farther north, however, in the Mynydd Tarw range, Mr. King finds clear evidence that the contortions are traversed by the cleavage, and preceded it.

Silurian.

Llandovery-Tarannon.—In completing the examination of the Silurian rocks of the great Llangollen syncline lying within Sheet 121, Mr. Smith detected the presence of Llandovery rocks north of the Dee near Corwen, by characters similar to those found applicable last year in the Cricor area (see 'Summary' for 1912, p. 9). South of the Dee Mr. Wills notes that while the graptolites show that both Llandovery and Tarannon rocks are present, it is usually difficult to separate the two formations, but that as in Mr. Smith's area, the Llandovery deposits are more or less characterised by their speckled aspect.

On the flanks of Cyrn-y-brain a thin band of graptolite-shales has been used to provide a line of separation. This band is accompanied by a thin purple bed over the eastern part of the area. On Cyrn-y-brain the series appears to be much thicker than at Glyn-Ceiriog, but this may be partly due to reduplication by isoclinal folding. Near Corwen the Llandovery rocks cover a large area as a result of gentle folding.

In the Tarannon group, Mr. Wills finds graptolites at several horizons, so that comparison becomes possible with the typical Tarannon area. On Cyrn-y-brain the group is composed of slates and roughly cleaved 'paste-rocks,' usually grey-green, sometimes banded with blue (and then occasionally becoming black graptolitic slates) and sometimes purple.

The purple bands are found on the south side of Cyrn-y-brain, and are of interest, since a similar lithology is known in the Tarannon of South Wales and Westmorland. Their recognition is useful as a key to the details of the folding.

The topmost beds of the Tarannon are dark-blue splintery and tough slates, rather thick and well-bedded and usually almost unfossiliferous. These appear to represent the passage beds found by Mr. Smith at Mynydd Cricor and the *Monogr. crenulatus* beds mentioned in 'Summary' for 1912, p. 10. They have now been recognised all round the Llangollen syncline.

Below these on Cyrn-y-brain is a group that is in places fossiliferous and has yielded *Phacops* cf. *elegans* (Sars and Boeck) and *Acidaspis*.

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Wenlock-Ludlow.—In finishing the survey of the north-west corner of Sheet 121, west of Nant Clwyd, Mr. Smith found that the area consisted chiefly of Ludlow rocks containing graptolites. The strata lie in gentle folds with east-west axes. Respecting the Corwen district, Mr. Smith reports that a thrust-plane, developed at the base of the Pen-y-glog Grit, cuts out varying amounts of Wenlock shale in the different faulted strips.

In the Llangollen district Mr. Wills has mapped a considerable area of the Wenlock-Ludlow beds. He remarks that the *Cyrtograptus murchisoni* beds at the base of the Wenlock are quarried throughout this district for roofing-slates and are everywhere of extremely uniform lithology. They are rather earthy-weathering banded slates of a dark-grey tint.

Above the roofing-slates near Carrog there is a strong development of grits—the Pen-y-glog grit—but where this is absent, as it usually is in the Llangollen district, the roofing-slates are succeeded by an unfossiliferous group of blue and grey slates with thin sandstones that are often uncleaved. In this series probably lies the junction of Wenlock and Lower Ludlow.

North of the Dee no accurate succession has been made out above this, partly because of the remarkable sameness of the beds and partly on account of the complexity of the structure. The strata ring an infinite variety of changes on slate, sandy-slate, siliceous flaggy sandstone, and calcareous flags.

North of Llangollen there seems however to be the following downward succession:—

1. Ashy-looking practically uncleaved mud-stones, tough flags and shales	Dinas Bran beds.
2. Irregular calcareous flags alternating with thin roughly cleaved shales	Flaggy horizon.
3. Thin-bedded slates alternating rapidly with thin-bedded sandy uncleaved shale	Slab horizon.
4. Thick-bedded grey thickly-cleaved slates, alternating with calcareous sandy bands, poorly cleaved and often impersistent	Pentre-dwfr Slate Vein.

Probably all these are referable to the Lower Ludlow. Their thickness must amount to several thousand feet. Fossils are extremely rare, although the lithological aspect of the rocks suggests deposition in shallow water.

Lower Carboniferous.

Carboniferous Limestone.

In mapping the remaining portion of the Lower Carboniferous escarpment north of Llangollen, Mr. Wedd has been able to follow out the subdivisions of the Carboniferous Limestone Series that he adopted in his previous work as described in the 'Summary'

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for 1911, p. 7. These subdivisions, in brief summary, are as follows in descending order:—

(*g*)	More or less sandy grey and brownish limestone about	25 ft.
(*f*)	Calcareous grits and sandy limestones, both often pebbly; cross-bedded oolitic sandy limestone in lower part, about	100 ft.
(*e*)	Dark and lighter grey thin-bedded limestones, about	250 ft.
(*d*)	Massive and thin-bedded limestones, creamy white or with rubbly bands and, locally, purple shales, maximum	420 ft.
(*c*)	Dark and lighter grey earthy limestones with thin shaly partings	maximum 480 ft.
(*b*)	Thin-bedded grey earthy limestones and grey calcareous shales	
(*a*)	Red pebbly sandstones and conglomerates with some purple shale.	

(*a*) The basement beds, thinning out northward below Craig Arthur and disappearing also southward near Castell Dinas Bran, have an outcrop about 2½ miles in length. Their southerly extension is actually cut off by the Carboniferous boundary-fault, but originally they must have died out before reaching Fron on the south side of the Dee, where higher beds of the limestone rest on the Silurian. The basement beds, where seen in exposures NNW. of Dinbren-uchaf, and in the material thrown out from old shafts, consist of dull-red, somewhat earthy, more or less pebbly sandstones and conglomerates, with pebbles of similar sandstone, Silurian slate, and quartz; and with subordinate beds of purple or crimson shale containing gravel-seams composed of rolled slate-fragments. This shale with slate-gravel precisely resembles a bed in the lower part of (*d*).

The junction of the lower grey limestone (*b* and *c*) with the basement beds is nowhere exposed, but blocks of pink limestone below Craig Arthur, where a former exposure of the basement beds is now buried under scree, probably come from this horizon.

The limestones of this group vary from a slightly rough-textured earthy, sometimes bituminous type, often fissile or platy, and weathering with a brownish crust (hence Morton's term 'Lower Brown Limestone'), to a fine-textured smooth type weathering with a pale bluish-grey crust and comparable in texture with the 'porcellaneous' limestone of the white limestone group.[1] In the higher part of the group, shaly beds become fewer and thinner, and some of the limestones thicker.

The lower grey limestone thins out completely both northward and southward before reaching Minera and Fron respectively. It passes up rather suddenly into the overlying white limestone. A description of the beds above this group was given in 'Summary of Progress' for 1911 (p. 7).

Of the zonal stratigraphy Mr. Wedd reports that, so far as the collection and determination of fossils have gone, the sandy limestone (*g* and *f*), the upper grey limestone (*e*), and at least the topmost 30 ft. of the upper white limestone (*d*) fall into the middle or *Floriformis* subzone (D2) of the *Dibunophyllum* zone of the south-western and Midland provinces, no evidence of the higher subzone or phase of *Cyathaxonia* (D3) having been found in this

[1] 'Summary of Progress' for 1911, p. 8.

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district, perhaps owing to the sandy conditions; that probably the whole of the lower white limestone and all or nearly all the lower grey limestone should be assigned to the lower *Dibunophyllum* zone (D1); and that it is uncertain whether any part of the *Seminula* zone (S) is represented in the lower grey limestone,[1] while the basement-beds afford no fossil evidence of their age.

The sandy limestone contains a few, the upper grey limestone many, species of corals and brachiopods essentially characteristic of the *Floriformis* subzone; and *Lonsdalia floriformis* Flem. occurs in the higher beds of the upper white limestone as well as throughout the upper grey limestone.

Corals are not abundant in the lower white limestone. *Dibunophyllum* is not common, and none of the clisiophyllids of the *Floriformis* subzone have been obtained. But *Cyathophyllum murchisoni* E. and H. and *Lithostrotion martini* E. and H. are not infrequent, and several species of gasteropods occur.

Few corals have been found in the lower grey limestone. The most conspicuous fossil is a large *Productus*, described as *P.* cf. *giganteus*, abundant at several horizons throughout, as in the Lower *Dibunophyllum* zone of the Midlands. But the form known as *Daviesiella llangollensis*, differing from the above only in the possession of an 'area,' has not been obtained. Mr. J. Pringle has collected and determined *Productus* cf. *corrugatus* M'Coy and a *Productus* apparently identical with *P.* aff. *globosus* Garwood of the Lower *Dibunophyllum* Zone of the North of England. He has also recognised the characteristic little crustacean of the lowest shale beds as *Cytherella sp.*, this being apparently Morton's '*Leperditia suborbiculata*, Munster.[2]

MILLSTONE GRIT.

It was mentioned in last year's 'Summary' (p. 12) that the quartzose sandstones of Pen-y-mynydd, two miles south of Hawarden, though classed with Lower Coal Measures on the Old Series map bore a close resemblance to the Millstone Grit of Hope Mountain. In mapping the continuation of these sandstones northward to Hawarden, Mr. King has been able to establish that they are of Millstone Grit age by the discovery of marine beds equivalent to the Holywell shales, overlying the gritty series, on the east side of their outcrop.

The grits form a ridge of high ground running from Hawarden to Pen-y-ffordd, and can be examined in many old quarries. In the majority of these they are medium-grained, hard, and quartzose, in places flaggy and sometimes slightly false-bedded or pebbly.

The dip has an average value of about 10° to the east, while the greatest width of outcrop is $\frac{3}{4}$ mile, so that an estimate of their thickness may be given as 600 ft.

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[1] See W. Hind and J. T. Stobbs, 'The Carboniferous Succession below the Coal Measures in North Shropshire, Denbighshire, and Flintshire,' *Geol. Mag.*, dec. v, vol. iii, 1906, p. 497.

[2] 'The Carboniferous Limestone and Cefn-y-Fedw Sandstone of the country between Llanymynech and Minera, North Wales.' London, 1879.

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The grit-ridge is cut off from the Coal Measures on the west by a fault, which is visible where it crosses the Hawarden-Wrexham road, and also in the stream, at a small waterfall, below Tinkersdale Cottage, where it throws the grits against black shales.

LOWER COAL MEASURES.

Holywell Shales.

To the east of, and overlying the grits described above, Mr. King finds marine shales and sandstones with fine gannister beds. Warren Dingle affords a continuous section for a mile, and shows that next above the grits there lie black goniatite-shales which are followed by felspathic sandstones with some cherty beds. Above these are more goniatite- and lingula-shales with impure calcareous bands and sandstones.

These are succeeded by speckled sandstones and black papery shales, with a fire-clay and a thin gannister with a trace of coal, which are the highest beds exposed in the dingle. The dip of the marine beds is easterly and varies from 5° to 20°. Assuming an average inclination of 14°, a thickness of about 600 feet is indicated for the series, so far as it is exposed to view.

The fossils obtained from it include:—

Gastrioceras sp.
Glyphioceras bilingue (Salter)
Pterinopecten papyraceus (J. Sow.)
Posidoniella laevis (Brown)
Lingula mytiloides (J. Sow.)

The sandstones at the lower end of Warren Dingle, and those seen in the railway-cutting at Babylon, Upper Kinnerton, and in the dingle of Brad Brook, lie above the marine beds and are probably on the horizon of the Gwespyr sandstone.

On the opposite or western side of the ridge of Millstone Grit, in the area surveyed by Mr. Wedd, the Lower Coal Measures brought in by the fault above-mentioned probably include an equivalent of the upper part of the Holywell Shales, though no marine fossils have been detected in the scanty exposures.

The productive Coal Measures of Buckley and Ewloe are brought in by another fault with a strong westerly downthrow, and in the tract between the two faults practically no coal has been found, though several trials have been made. The outcrop of the measures is for the most part drift-covered, but the railway-cutting north-east of Buckley Junction exposes a sandstone 100 feet or more in thickness, overlying a greater thickness of shale. Mr. Wedd considers that the sandstone and shale probably represent the Lower Coal Measures (Gwespyr Sandstone and Holywell Shales) of the western district.

The outcrop of Lower Coal Measures referred to runs, in a north-westerly direction, by Aston Bank, Aston, Wepre Hall, Connah's Quay, and Flint, and is continuous with an elongated tract in which only measures below the Main Coal are present. The outcrop of these follows an anticlinal axis of no great elevation, which probably passes under the Dee valley immediately north of Flint, and seems in the opposite direction to be one with an anticline

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that brings up the Lower Coal Measures and the Millstone Grit south of Hawarden.

The marine shales at Leeswood mentioned in last year's 'Summary' have been further examined by Mr. Lamplugh, but their position in the sequence still remains doubtful. Though closely resembling the Holywell Shales both in lithological character and fossil-contents, they are bounded on three sides by productive Coal Measures, while the faults proved by mining in the vicinity do not favour the supposition that the Holywell Shales may be brought to the surface at this place. The fossils found here include *Gastrioceras carbonarium* (von Buch), *Glyphioceras reticulatum* (Phill.), *G.* cf. *bilingue* (Salt.), *Pterinopecten papyraceus* (J. Sow.), *Posidoniella laevis* (Brown), *P. minor* (Brown), and *Lingula mytiloides* (J. Sow.).

MIDDLE COAL MEASURES.

In the northern part of the Flintshire Coalfield Mr. Wedd finds that a shallow but important syncline, extending south-eastward from near Flint by Northophall and Ewloe Green, brings in the Main and higher coals and the Buckley fireclays. The syncline, and to a less degree the bordering anticlines, are traversed by faults trending between north and north-west, for the most part with westerly downthrows, which to a great extent counteract the effect of folding in the matter of elevation.

The measures below the Main Coal contain the Flintshire Wall and Bench, the Yard and the Premier Coals in descending order, and also include some variable sandstones, that above the Yard Coal having, in the district of Buckley, a pebbly base with rather large quartz-pebbles. Below the Premier Coal are several sandstones of no great thickness, some of them rather coarse and quartzose, with pebbly seams. Black and carbonaceous hard brittle shales are characteristic of the lowest measures up to a horizon above the Premier Coal. It appears to be the lowest beds of the Middle Coal Measures that contain the brick-clays worked with some gannister at Connah's Quay.

The strike of the Main Coal, modified by numerous faults, curves eastward and southward from Queen's Ferry across the Connah's Quay anticline and thence westward to Northophall and southward across the syncline to Buckley.

On the south-east side of this line higher measures contain, in ascending order, the Rough, the Brassy, the Hollin, and the local Upper Main coals. Above the Hollin Coal a massive sandstone, the Hollin Rock, is always present, varying in thickness from 30 or 40 ft. to about 200 ft. farther north, at Mare Hay.

Several of the coals are interrupted by 'wash-outs' in the Buckley neighbourhood. In a part of the workings of the Elm Colliery north of Buckley a downward encroachment of the Hollin Rock cuts out one or two small coals and the Hollin Seam below. The Main Coal also has been removed in a similar manner, as well as the Yard Coal here and farther south by the downward development of a third sandstone. At the Mountain Colliery, Buckley, a sandstone encroaching downwards from its usual position some little distance above the Main Coal and reaching the roof of that

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seam, becomes a remarkable breccia-conglomerate in its basal part and at one or two higher horizons. Parts of it contain large jagged fragments of a laminated sandy shale or shaly sandstone, while other parts include only rounded pebbles of sandstone, the one type suggestive of plucking from the sides of an erosion channel, the other of rolling on a stream-bed.

In mapping the Buckley district Mr. Wedd paid particular attention to the well-known fireclays so extensively worked there. He finds that this particular group of strata comes on a short distance above the Hollin Rock where that rock is comparatively thin, or almost immediately above it where thick. The exposed sequence of these beds in descending order is as follows:—

6. Hard massive quartzose fine-grained sandstone, usually white, but rather felspathic and pinkish-grey in some of the higher beds, weathering with a purplish brown crust; with subordinate beds of white siliceous clunch, very fine-grained, and often full of sphaerosiderite, beds of purple shaly clay and locally of pale-green clayey flags; a downward passage into—
5. White siliceous clunch or silt-rock, very fine-grained and often full of sphaerosiderite.
4. Purple mottled clay, passing down irregularly into—
3. Soft leaden-grey saponaceous shaly clay, more or less purple-stained in the upper part, sometimes with one or two little coal-seams in the lower part.
2. *Coal*, becoming northwards a mere streak of carbonaceous shale.
1. Soft grey shaly clay, or harder whitish silty clay sometimes weathering purple.

Individual beds vary greatly in thickness and extent. The exposed beds, of which approximately the upper half is mainly sandstone, have a thickness of not much more than 100 ft., but they form only the lower part of the group. A boring north of the Elm Colliery workings, Buckley, proved some 400 ft. of strata above the base of these fireclays, with sandstones and purple clays in the lower part. This fireclay group crops out only in the neighbourhood of Buckley, where faults with westerly downthrow and the general eastward dip have co-operated to produce three separate outcrops. But there is reason to believe that the beds have a wider distribution under drift, and that they are present in the north of Flintshire wherever the upward sequence continues above the Hollin Rock, *e.g.*, at Mancot, Mold, and probably Bagillt.

Mr. Wedd remarks that though there is some appearance of discordance locally at the base of the white sandstones, this is probably attributable to differential movement in the deformation of the strata; for beds of clay are sometimes curled up and truncated by the sandstone. Moreover, these Buckley beds participate fully in the folding and faulting by which the Middle Coal Measures are affected, whereas the Upper Coal Measures, not far distant, around Flint, have been shown to be strongly unconformable.[1]

The Buckley Fireclay group might be regarded as a transition group between the Middle and Upper Coal Measures, but that it occupies roughly the same position above the Main Coal as the Cefn Sandstone of Denbighshire, which belongs essentially to the Middle Measures, and lies some distance below the red Ruabon

[1] 'Summary of Progress' for 1912, p. 14.

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Marls. These Buckley beds may best be considered as indicating a partial, local and temporary anticipation of Upper Coal Measure conditions, at a stage at which Middle Coal Measure conditions still prevail farther south.

Mr. Wedd notes that fresh-water shell-beds, remarkably rare in the Denbighshire Coalfield, are apparently more frequent in Flintshire, where *Carbonicola sp.* occurs abundantly in the shale-roof of the Main Coal at Queen's Ferry and elsewhere, while similar shell-beds are stated to be present in the roof of the Two-Yard at Point of Ayr and in that of the Wall and Bench at Buckley (probably the same coal); also in the roof of the Durbog seam at Point of Ayr, and of the Six-Foot Mine at Neston on the Cheshire side of the Dee. No evidence for marine bands in the Middle Coal Measures of Flintshire has come to Mr. Wedd's knowledge, except the record of a *Lingula*-bed occurring at 18 ft. above the Four-Foot Coal at Bettisfield Colliery, Bagillt.

UPPER COAL MEASURES.

At Flint Mr. Wedd now finds that the unconformable Upper Coal Measures[1] descend to a lower horizon of the denuded Middle Measures on the south and east sides of the town than on the west side. For, at the old Dee Green Colliery what are believed to be the lowest coals of the district were raised at little depth beneath the base of the red measures, the Main and several lower seams having been lost by denudation. Farther east the unconformability may descend still lower, as at Rockcliff red Upper Coal Measures are faulted in amongst some of the lowest measures that crop out in that district.

TRIAS.

BUNTER.

In completing the mapping of Wirral Mr. Simmons has surveyed the areas of Bunter in the northern part of the peninsula, where, however, the outcrops are frequently hidden under a thick cover of drift. The Lower Mottled Sandstone is not reached in this part, unless the low-water reef in the Dee estuary known as Seldom Seen Rocks, lying off 1½ miles S.W. of West Kirby, belong to this subdivision. Mr. Simmons found that the reef consisted of coarse red sandstone without pebbles, exactly resembling some of the coarse pebble-less sandstones of the Pebble Beds and different from the sandstone of finer grain that constitutes the Lower Mottled Sandstone as seen in the more southerly part of Wirral. Therefore, if the lithological characters are to be trusted, this reef indicates a further extension of the Pebble Beds under the estuary. The reef of Caldy Blacks, nearer inshore 1¾ miles E.S.E. of the Seldom Seen Rocks, was also examined and found to consist of similar sandstone showing a glaciated surface passing under boulder-clay, the markings having a direction of S.15°E.

The Bunter Pebble Beds form Hilbre Island and a long reef, which extends, in parts above high tide, for nearly two miles south-eastward from it. The exposure consists for the most part

[1] 'Summary of Progress' for 1912, p. 14.

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of sandstones of the normal Pebble Bed type, sparingly pebbly, but exhibits also, in the northern part, an interesting band of breccia, averaging a foot in thickness and containing subangular fragments of Carboniferous sandstone, vein-quartz, and a variety of other rocks. A similar breccia-bed is seen on the mainland at Hilbre Point. On the Mersey side of Wirral, Pebble Beds of normal Wirral type, with but few pebbles, are well exposed on the shore north of New Brighton and in large old quarries at Tranmere, Birkenhead.

The Upper Mottled Sandstone is particularly well exposed on the western side of the peninsula in the ridges running south-eastward from West Kirby and in part of the Bidston ridge. In the former district it includes, among the typical soft fine-grained sandrock, a fairly persistent band of harder coarse-grained sandstone, averaging 3 ft. thick, which forms a traceable feature along the escarpment, and in many of its characters resembles the hard beds at the bottom of the Keuper. The position of this band is about 150 ft. below the top of the Upper Mottled Sandstone.

In Flintshire Mr. King re-examined and completed the mapping of the only exposure of the base of the Trias on the eastern side of the coalfield. This occurs 3½ miles S. of Hawarden, in a ravine of Brad Brook, where a red breccia of scree-like character is banked across the eroded edges of hard Carboniferous sandstones and shales, and passes upward into a soft friable red sandstone of Lower Mottled Sandstone type, in which the larger sand-grains are well-rounded.

In the Oswestry district (Shropshire) Mr. Wray mapped an area, south-east of Oswestry, which, though for the most part covered with drift and alluvium, is underlain by the Bunter sandstones. All three divisions are recognisable by their lithological character in the occasional outcrops, but the exposures are generally too limited to allow their boundaries to be fixed with certainty. From the extent of the Pebble Beds around Aston Hall Mr. Wray concludes that this division must extend farther westward than was shown on the Old Series map.

KEUPER.

The Keuper Basement Beds (see last year's 'Summary,' p. 11) have been mapped by Mr. Simmons in their well-defined outcrops near West Kirby, Frankby, Birkenhead, Wallasey, and New Brighton. They are generally red in colour on the western side of Wirral, but mostly buff or yellow on the eastern side. The softer sandy beds previously noted at the top of the group in the Heswall district (*op. cit.*, p. 11) have now been recognised also in the north-eastern part of Wirral.

The Waterstones are not frequently exposed, but a good section in this subdivision is revealed in a dingle between Thurstaston and Oldfield. From this section Mr. Simmons obtained small carbonised fragments of plants, one specimen of which was submitted to Dr. E. A. Newell Arber, who reports that it 'no doubt represents part of the node of a stem or branch of some Equisetalean genus.' The scantiness of indigenous fossils in the Trias of Wirral gives interest to this discovery.

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The Keuper Marl, in the few exposures to be seen in Wirral, is of a more sandy type than usual, so that its separation from the Waterstones is not distinct.

While collecting information regarding the deep wells of the peninsula Mr. Simmons examined the cores from the well-boring made at Ford in 1895-6, of which a record was published by the late G. H. Morton in 'The Geology of Liverpool.' The section throws light on the local grouping of the Triassic strata, and Mr. Simmons proposes the following revised classification:—Soil, 1 ft.; Boulder Clay, 45 ft.; Glacial sand and gravel, 16 ft.; Keuper Marl, 315 ft.; Waterstones, 139 ft.; Keuper Basement Beds, to 244 ft.; Fault-rock, 7 ft.; Bunter sandstone, probably Pebble Beds, penetrated to 32 ft. Total depth, 799 ft.

Glacial.

The wide tracts of boulder-clay in the northern part of Wirral were mapped by Mr. Simmons, who reports that Glacial sands, though abundant farther south, are of rare occurrence in this part of the peninsula. The Boulder Clay itself is less sandy in composition, this difference being probably due to the predominance of Keuper Marl as the underlying formation in the north and of Bunter sandstones in the south. The manner in which original features of the country have been obliterated by the drift deposits is strikingly exemplified by some of the borings for water, those at the Hooton waterworks revealing the presence of a drift-filled valley in the Bunter Pebble Beds, with its bottom at not less than 225 ft. below the present surface and 128 ft. below Ordnance Datum.

On the Flintshire side of the Dee estuary, in the tract S.E. of Hawarden, surveyed by Mr. King, similar results are shown by borings. Thus, Mr. King finds that at Davies' Farm, Lower Kinnerton, a boring proved 272 ft. of drift, mostly clay, without reaching the Trias, indicating that the rock-surface is here more than 230 ft. below O.D.; while other borings, east of Hawarden tend to show that the contours of the rock-surface below O.D. run nearly parallel to the present contours of the ground above O.D. Comparing this record with that of other borings further up the valley of the Dee, Mr. King remarks that if the rock-floor beneath Lower Kinnerton be in the channel of the pre-glacial Dee, the old river must have had a gradient enormously in excess of its present fall in the lower part of its course, and that probably the hollow is due in part to glacial erosion of the soft Trias.

The prevalent red-brown boulder-clay with ashy-grey joints, of this district, is best exposed in a brickyard at Cuckoo's Nest, near Pulford, and among the boulders dug out at this place Mr. King noticed a block of Lower Lias limestone with well-preserved examples of *Pleuromya crowcombeia* Tate. On the bare ridge of Millstone Grit south of Hawarden, glacial striæ were observed in several places, mostly with directions between S.5°E. and S. 20°E.

The irregular belt of sand and gravel lying about the 200 ft. contour on the drift-covered slope south of the Dee, mentioned by Mr. Wedd in last year's 'Summary' (p. 18), has now been

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traced by him towards Hawarden, where Mr. King finds that it swings southward through Hawarden Park and passes across Warren Mountain up to Cuckoo Hill. Beyond this place it is not traceable continuously, but may be represented by the isolated patches of sand and gravel occurring at about the some elevation between Higher Kinnerton and Hope.

In the Lower Palæozoic hill-district mapped during the year by Mr. Wills, Mr. King, and Mr. Smith, in the neighbourhoods respectively, of Llangollen, Glyn-Ceiriog and Llanrhaiadr-yn-Mochnant, the glacial deposits, occurring sporadically at all levels, but mainly in the valleys, were all found to be of the local type, with boulders from the Welsh mountains only. Evidence was found that the glaciation passed over even the highest summits of the areas surveyed, ranging up to 2,000 ft. above O.D. The slaty drift appears also to extend out to the lower ground S.E. of Oswestry, mapped by Mr. Wray, where it is associated with red sands derived from the local Trias; but in this quarter, along with the boulders of Silurian and Ordovician rocks, Mr. Wray found numerous blocks of reddish quartzite of which the origin is, as yet, uncertain. Although fragments of marine shells were detected in nearly all the localities further north where the 'foreign' or 'red' drift occupies the lowland, none have been found in this low-lying slaty or 'grey' drift.

Post-glacial and Recent.

The tracts of Alluvium and Blown Sand fringing the northern shores of Wirral were mapped by Mr. Simmons, who notes that the well-known 'forest-bed' of Leasowe is still exposed on the foreshore at Dove Point, showing stools of trees and prostrate trunks embedded in peat, but is being rapidly denuded by the sea. The alluvium of this area is partly of freshwater and partly of estuarine origin.

Mr. Wedd and Mr. King completed the mapping of the Dee flats around the head of the estuary, where again the estuarine deposits merge into fresh-water and peaty sediments in the side-inlets.

South-east of Oswestry Mr. Wray surveyed an extensive area of nearly flat ground connected with the River Morda and its tributaries, shown on the old map as alluvium. This flat is not a recent alluvium and lies for the most part well above the present flood-level. It appears to be composed partly of slaty flood-gravels of considerable antiquity, and partly of clay-wash with slate-fragments, not unlike the local boulder-clay in composition though perhaps of different origin and later distribution. The source and mode of deposition of this anomalous material may be elucidated when the survey of the surrounding country has been done.

In the hill-country to the westward it is noted by Mr. Smith, Mr. Wills, and Mr. King that most of the side-streams on entering the larger valleys have thrown down broad fans or deltas of gravel which the main stream is not now sufficiently powerful to remove. This condition is evidently connected with the heightened gradient of the side-valleys as they approach the main valley, a point commented on by Mr. Wills in last year's 'Summary.'

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2.—Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.
T. C. Cantrill, B.Sc.
C. H. Cunnington, B.Sc. } Geologists.
T. Eastwood.

The survey on the six-inch scale of the Warwickshire Coalfield has been continued in the Coventry (169) and Birmingham (168) Sheets of the one-inch map. In South Staffordshire the examination of some recent mining developments has afforded much information bearing on the extension of the Coalfield to the east and west.

Pre-cambrian and Cambrian.

The survey of the small but scientifically interesting and economically important area of Cambrian and Pre-Cambrian rocks north-west of Nuneaton has involved much detailed work, not only in actual surveying but also in the collection of material relating to the local industries of quarrying, preparing road-metal, and brick-making.

With the previous descriptions of the geology by Dr. A. Strahan, Prof. C. Lapworth, and Prof. W. W. Watts, the results obtained by the present survey are in general agreement; but considerable modification of the old one-inch map has been made in the mapping of the diorite masses between Griff and Marston Lane. Mr. Eastwood, who surveyed this area, finds there can be no doubt that the mass immediately south of Chilvers Coton is the same as that of the Griff quarry, repeated by faulting, since in both cases the base is characterised by a coarse type of rock having the aspect of hornblende picrite. At Marston Jabbett the diorite, represented as a single outcrop, consists really of two sheets, separated by shale, of which the upper is exposed on the east and west flanks of an anticline, while the lower sheet, which runs irregularly through the shales, comes out at intervals along the axis.

Carboniferous.

In Warwickshire the Carboniferous succession includes only representatives of the Upper Carboniferous rocks, and so far there are no indications that the Lower Carboniferous was ever deposited there. Continuing the mapping south of Nuneaton Mr. Eastwood reports that the Coal Measures are mostly concealed under drift, and south of Bedworth completely so. Here, therefore, the mining operations afford almost the only information available for fixing the position of outcrops and determining the characters of the measures. The total thickness of the Lower Grey Measures at the Charity Colliery amounts to 510 ft. and to 430 ft. at the Hawkesbury Pits, two miles to the south. Generally, southwards along the strike and westwards in the direction of dip, there is a gradual thinning away of the measures between the Two Yard and Slate coals; the two seams in the Stockingford district are separated by 90 ft. of strata, while at

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Bedworth and to the west, they, with the intervening seams, come together and form the Thick Coal of Warwickshire.

The Lower Red Marls (Etruria Marls) of the Upper Series are not readily recognisable as a constant group of red measures, but in most of the shaft-sections there occur about 150 ft. of strata, from 50 to 100 ft. above the Four-Foot Coal, which are described as red and grey binds with mingled ground and coarse grey sandstones, the latter presumably representing the Espley Rocks.

Here, as in the northern part of the Coalfield, grey sandstones predominate in the basal beds of the Upper Grey Measures (Halesowen Group), while the higher beds consist chiefly of grey marl with a thin band of limestone (Index Bed) about 150 ft. from the top. The limestone contains *Spirorbis* and has been traced by old surface-workings and shallow shafts to the neighbourhood of Bedworth. The same types, with the limestone strongly developed, were met with by Mr. Cunnington in the small inlier at Arley, where the highest beds, by the intercalation of bands of red marl, pass up imperceptibly into the Keele beds.

KEELE BEDS AND CONFORMABLE OVERLYING RED MEASURES.

The top of the Carboniferous succession in the district still remains indefinite. The suggestion referred to in the 'Summary of Progress' for 1912, p. 3, that in South Staffordshire a line between Carboniferous and Permian could be drawn at a height of about 900 ft. above the base of the Keele beds where certain conglomeratic beds make their appearance, has not been found applicable to the Warwickshire Coalfield, though many excellent opportunities occur of examining and tracing the individual outcrops. In a large tract surveyed by Mr. Cunnington between Arley, Corley, and the western boundary fault, sandstones and conglomeratic bands are developed at various levels several hundred feet above the base of the Keele beds. The variation in level was attributed to unconformity by Mr. R. D. Vernon (*Quart. Journ. Geol. Soc.*, vol. lxviii, 1913, pp. 587–638), but it is explained by the rapid lateral passage of ordinary sandstones into conglomerates. Hence, the lowest conglomerates at different places are not prolongations of a single bed but occupy different horizons. These deposits are, in fact, untrustworthy as stratigraphical indices, and no unconformity can be inferred from their mode of occurrence. Stratigraphically the whole of the red series, so far as yet seen, is in normal sequence, but it is still possible, notwithstanding, that the red series may include more than the upper Carboniferous subdivisions as usually defined. This question can only be settled by palæontological evidence, which is at present scanty and unsatisfactory. In North Staffordshire, where the Keele beds were first established as the uppermost subdivision of the local Coal Measures, the exposed sequence probably does not extend as high as the lowest beds of conglomerate in the present area. It will be safer, therefore, for the present to restrict the term 'Keele Group' to the equivalent of the North Staffordshire deposits, and to regard the correlation of the higher beds of Warwickshire and South Staffordshire as still open to question.

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Though no hard and fast line can be drawn, Mr. Cunnington recognises the following sequence of these red measures in descending order:—

(3) Upper Group—Red marls and soft red sandstones.
(2) Middle Group—Hard red sandstones with 'calcareous' conglomerates.
(1) Lower (Keele) Group—Red marls and red sandstones with three *Spirorbis*-limestones.

Of this sequence only the lowest group can be definitely correlated with the Keele Group of North Staffordshire. Owing to the false-bedded nature of the deposits it is extremely difficult to get an accurate idea of the thickness of the whole series. It is clear, however, that Mr. Howell ('Geology of Warwickshire Coalfield,' *Mem. Geol. Surv.*, p. 30), did not over-estimate it at 2,000 ft., for borings have shown a thickness of 1,000-1,250 ft. for the lowest non-conglomeratic group, while the middle group cannot be less than 1,000 ft. An estimate of 2,500 for the three groups can scarcely be too large.

(1) The Lower (Keele) Group is characterised by three bands of *Spirorbis*-limestone, which have proved of the greatest value in mapping, and there can be little doubt that they are continuous over the greater part of the area. Owing to contemporaneous erosion, however, a band may be locally absent, but in this case, its broken debris, together with marl-fragments, may be found cemented together to form a pellety rock. The frequent occurrence of pebbles of *Spirorbus*-limestone in the conglomeratic bands of the Middle Group may also perhaps be accounted for by a similar action. Near Ansley Mill, two thin beds of limestone occur, and can be traced for some distance. The lower was penetrated at Arley Colliery, where it was 120 ft. from the base of the group, and had a thickness of 1 ft. 6 in. It agrees in position exactly with one found by Mr. Eastwood in the northern part of the coalfield, in the neighbourhood of Baxterley. The higher of the two limestones crops out in the cutting west of Arley Tunnel, where it lies at a height of 450 ft. from the base of the group. It is associated with a series of hard sandstones which form a prominent escarpment, dominating the marl plain to the west. South of Stockingford, in the ground surveyed by Mr. Eastwood, a dark-blue limestone occurring in bright-red marls, and, as at Arley, associated with pellet-beds, has been traced for a distance of about 2½ miles between Newdegate Mineral Railway and Longford. In a cutting on that railway, near the bridge, *Spirorbis* is not uncommon in the limestone-bands, but it is scarce in the dark limestone, 2 ft. thick, which forms the floor of the large clay-pits of the Foleshill Brick Co. close to Longford Station. The highest *Spirorbis*-limestone, as yet known, is seen in the neighbourhood of Over Whitacre, and again at Maxstoke, as described by Mr. T. C. Cantrill (*Geol. Mag.*, dec. v, vol. vi, 1909, p. 452). The position of this band varies between 1,000 and 1,200 ft. above the base of the series, and, though only a few inches thick, it has been traced for over six miles.

(2) The middle subdivision, lying above the Keele beds proper, consists of three groups of sandstones, often conglomeratic, separated by two bands of marl. But this development is confined

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to the central part of the area surveyed, for the lower marl-band passes into sandstone westwards. As a rule, the lower conglomeratic beds contain many pebbles of Carboniferous Limestone, and are identical with those described last year from Hamstead, in South Staffordshire. They can be seen in the cutting at Arley Station, where the lenticular character of the individual beds is well shown. The base of the series is indefinite, and the lowest beds may merge into the Keele or *Spirorbis*-limestone group, a feature well exemplified in the ground between Over Whitacre and Maxstoke. From the former place the highest *Spirorbis*-limestone can be readily traced past Dove House Farm and Hill Farm to Maxstoke. At Over Whitacre, the lowest conglomeratic band is some distance above the limestone, but at Dove House Farm a sandstone immediately above the limestone assumes the conglomeratic character. Between this point and Hill Farm the sections are particularly clear: in the north the sandstone below the limestone is of the usual pellety type, but passes southwards into a coarse conglomerate identical with that found at Arley Station. It is therefore evident that the incoming of conglomerate does not mark a fixed horizon. At Hill Farm and at Spring Pools, Packington, the measures below it contain badly preserved calcareous algae which Professor Garwood refers to *Spongiostroma*. (*Geol. Mag.*, dec. v, vol. x, 1913, p. 549.)

Near Exhall, on the eastern side of the Coalfield, a conglomerate similar to that described above occurs at a height of 800-900 ft., as estimated by Mr. Eastwood, above the base of the Keele Group.

The second conglomeratic belt is best developed at Corley, where it presents a rather exceptional type. It comprises dull-reddish sandstones with irregular lenticular masses of coarse breccia, so numerous that the belt can be mapped as one continuous breccia-bed. In it Carboniferous pebbles are almost absent, but sub-angular pieces of Silurian sandstone, coarse white quartzite, and other older rocks are abundant. From Corley the belt can be traced to Hollyberry Hall, but west of this point it becomes subdivided by marl-bands, and, moreover, passes into the more prevalent type with limestone pebbles. Here, too, the conglomerate is extremely coarse, and, in a quarry 600 yards south-west of the Hall, contains fragments over 6 inches in length. Some of the limestone-blocks contain *Spirorbis*, as is the case in other neighbouring localities at this horizon. Such large and irregularly shaped pieces of limestone have not been found in the other conglomerate beds, and their presence here suggests a local derivation from a band higher than any hitherto met with.

Separated from the Corley beds by a well-marked belt of marl, the third group of sandstones and conglomerates is well exposed at Allesley. It was from these beds that Buckland in 1836 (*Proc. Geol. Soc.*, vol. ii, no. 48, pp. 439-440), described silicified tree-trunks. The trunks occur prostrate, embedded in hard sandstone, and have been met with at many places in the village, where recently one measuring over 6 ft. in length was found opposite the Rainbow Inn. A similar bed occurs at the same horizon at Meriden, and all along its outcrop, for over two miles, the fields are littered with pieces of fossil wood.

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(3) The Upper Group crops out at Eastern Green and Hockley. It is made up of vividly red marls with bands of thin greenish-grey sandstones, not unlike those present in the Keuper Marls. Beds of this type were found in the Little Aston boring (see 'Summary of Progress' for 1911, p. 27), where their bottom proved to be over 1,600 ft. above the base of the conglomeratic beds (2).

Trias.

The Trias of East Warwickshire comprises only the so-called Lower Keuper Sandstone and the Keuper Marls, the Bunter formation being unrepresented.

The Lower Keuper Sandstone forms a narrow outcrop fringing the coalfield on the east and west. On the east it crops out around Chilvers Coton, where it has been mapped by Mr. Eastwood. It is a soft, buff-coloured, rather massive rock, frequently conglomeratic near the base. On the south side of the Midland Quarry the conglomerate contains large pieces of the underlying diorite and quartzite, with fragments of Stockingford Shales and rounded pebbles similar to those found in the Bunter Pebble Beds. A small outlier, not hitherto recorded, occupies a hollow in the Cambrian shales a little east of the bridge which crosses the railway between Nuneaton and Stockingford.

Wherever seen, the upper beds of the Lower Keuper Sandstone consist of thin bands of red and white sandstone interstratified with beds of red marl, the whole corresponding to the 'Waterstones' group of the North and West Midlands. They are seldom seen in section on the east side of the coalfield; and on the opposite side, north of Hermitage Farm, Maxstoke, as far as Shustoke, are faulted out, for Mr. Cunnington finds evidence that beds some distance up in the Keuper Marl are thrown against Keele beds. South of Hermitage Farm, the fault bifurcates, and high beds of Keuper Marl on the west abut against low beds on the east, from below which, at Meriden, a soft white micaceous sandstone appears, evidently one high up in the Lower Keuper.

East of Nuneaton the Keuper Marl extends beyond the margin of Sheet 169 as far south as Leire. South of Leire the Lower Lias is represented on the Old Series Map as setting in above the Marl, but no evidence for its presence there has yet been obtained, and at two places in the bed of the Swift, below Lutterworth, the presence of red clay with small fragments of skerry sandstone, noted by Dr. Gibson, suggests an outcrop of the Marl. In the tract around Hinckley, surveyed by Mr. Cantrill, the surface is occupied by Glacial deposits, below which the Keuper Marl emerges towards Stoney Stanton and Sapcote, with the Archaean syenite projecting through it in the form of knolls. Consisting chiefly of red marls, the Keuper here contains also occasional thin bands of grit and coarse sand, derived presumably from the waste of the local igneous rocks in Triassic times. Such grit-bands have been noted at the Clint Hill quarry at Stoney Stanton, where also the beds of marl can be seen curving up the sides of the syenite at angles of 15°, and overlapping each other. Farther north, the same phenomena of overlap are particularly well shewn at the Enderby and Stoney Stanton

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Granite Co.'s quarry at the Yennards near Potters Marston. A considerable area of Keuper Marl has been mapped by Mr. Eastwood to the north of Nuneaton, but there are no good sections. The junction of the Keuper with the Cambrian and Pre-Cambrian, and of the Keuper Marl with the Lower Keuper Sandstone southwards to the White Stone, is considered to be a faulted one.

On the western side of the coalfield, between Coleshill and Hampton, Mr. Cunnington recognises an outcrop of the Arden Sandstone group of Dr. Matley (*Quart. Journ. Geol. Soc.*, vol. lxvii, p. 254). It occurs about 800 ft. above the base of the Keuper Marl, and its outcrop has been followed on the west side of the River Blythe as an almost continuous band. It is also found on the eastern side of the river near Little Packington. The group consists of bluish-green shaly marl interstratified with red beds, and contains one or two bands of coarse whitish sandstone. At Coleshill, two such bands occur, each 4 ft. thick; and though the upper one can be traced for a mile, the lower dies out abruptly. At Hampton one of these bands becomes brecciated and contains fish-scales.

Glacial.

The borderlands of the Warwickshire Coalfield are largely covered with drift, from beneath which the limited outcrops of Trias appear only at wide intervals. On the east side the solid formations are covered, in places to a depth of 150 ft. or more, by laminated clays, bedded sands, and gravels, derived from the 'Eastern' (North Sea) ice-sheet; in the west by material, sometimes as much as 60 ft. thick, originating from the 'Western' (Irish Sea) ice-sheet. Thus the products of two ice-sheets meet within the present area, but the survey has not yet extended far enough to show their relationship.

The 'Eastern' drifts are made up chiefly of stratified yellow sands, flint-gravels, and brown laminated silty clays, with some intercalations of red sands and clays. The 'Western' drifts are devoid of flints and composed of material derived from the Triassic rocks; they are arranged far less regularly than the deposits of 'Eastern' origin. Erratics are rare in both areas and no signs of unstratified boulder-clay of the usual type have been met with, except, perhaps, at Bedworth.

Along the eastern margin of the map, between Leire and Newton, the beds mapped by Dr. Gibson consist of brown, laminated silty clays, from 10 to 40 ft. thick, resting on stratified yellow sands and flint-gravels from 15 to 30 ft. thick. Patches of sand and flint-gravel, possibly remnants of a higher bed, lie in hollows of the brown silty clays around Ullesthorpe and Ashby Parva. Since the deposition of the drifts, the country has suffered severe erosion, so that the valleys are cut down in places 50 ft. below the base of the sands, trenching into soft beds below; but for the present, owing to the absence of sections, it is not known whether these underlying beds belong to older Glacial beds or to solid formations. Whatever they are, their junction with the overlying sands is sharply accentuated by the latter giving rise to a narrow shelf, maintaining a nearly uniform level,

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readily traceable round the numerous drainage-valleys which intersect the district.

The ground between Leire and Burbage has not yet been surveyed, but around Hinckley Mr. Cantrill finds deposits similar to those above described arranged as follows in descending order:—

	Ft.
3. Brown clay, with flints, fragments of Chalk, pebbles of Jurassic limestone and derived fossils up to ...	30
2. Red sands, loams, clays and gravels, with abundant Bunter pebbles, up to	60
1. Brown laminated loam, silt and clay, with few or no pebbles in upper part, proved in borings to ...	50

The upper part of the laminated loam (1), which alone is well exposed, *e.g.*, in Hudson's brick-pits at Hinckley, is entirely free from pebbles; the lower part contains flints, Bunter pebbles, and lenticular beds of red sand. The red sands (2) are composed almost exclusively of Triassic materials, the included pebbles being derived mainly from the Bunter. Interstratified with the sands there are some lenticular beds of red clay, probably derived from the Keuper Marl, and also several thin bands of clay with flints and fragments of chalk. The brown clay (3) is badly exposed, and around Hinckley never exceeds about 30 ft. It resembles the lower part of (1) in containing abundant flints, pieces of chalk, fragments of Jurassic limestone, and derived fossils. The mapping shows that all the surface-relief of the district is attributable to the subsequent erosion to which the drift-materials have been subjected. The local three-fold sequence implied by the mapping is also confirmed by several well-sections at Hinckley, in which sands and gravels occupy an intermediate position between two beds of clay.

Large boulders, chiefly of igneous rocks, of which many appear to have travelled from Charnwood Forest, Stoney Stanton and Sapcote, lie on the surface; some have been found in the red sands (2) and in the upper brown clay (3), one from the latter being Carboniferous cherty limestone.

Three miles west of Hinckley, where the Keuper Marl is at the surface, Mr. Eastwood observes that the drifts end off with an indefinite and irregular boundary on a slope rising gently to the west. At Higham-on-the-Hill, Weston Hall, and Bulkington, the lower brown clays are succeeded by a series of bedded sands and flint-bearing gravels, overlain at Weston Hall by a brown clay. Between Nuneaton and Mancetter gravels with flints, resting on Keuper Marl, fringe the alluvium of the Anker. Near Attleborough these gravels pass from the alluvial flats on to higher ground to the west. South of Chilvers Coton and west of the narrow driftless outcrop of Trias, Glacial deposits come on again. In the neighbourhood of Bedworth, where they are best exposed, Mr. Eastwood recognises a lower stiff, red-brown clay about 40 ft. thick, generally unstratified, though occasionally finely laminated as at Exhall. Boulders, though not numerous, include Jurassic limestones, 'skerries' from the Keuper Marl, and older local rocks, many of which are striated and polished. At the Hawkesbury and Bedworth brick-pit the sands and gravels above these clays contain, in addition to the usual flints, a few broken

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Bunter pebbles and a large number of flakes of Stockingford shale, together with pieces of diorite and fragments of 'skerry.' The presence of unstratified clays with included striated boulders affords almost the only signs of the presence of an ice-sheet. Even where patches of boulder-clay are found resting on the hard Cambrian quartzites the latter are unglaciated and their jagged edges project into the drifts. Possibly in Glacial times the Trias may have formed a protecting cap of no great thickness, which in nearly all cases has been removed and incorporated with the boulder-clay.

West of a line drawn from Stockingford to Newdegate Mr. Eastwood finds that the drift consists of isolated patches of clayey sand and gravel with abundance of Bunter pebbles, but no flints. A few scattered occurrences are noted by Mr. Cunnington on the more hilly ground formed by the Keele and associated beds, but west of the Boundary Fault Glacial deposits again occupy a considerable stretch of country along the Blythe valley between Shustoke and Berkswell, the prevalent type being that of the bedded sands and gravels which cover so considerable an area south-east of Sutton Coldfield, as mentioned in the 'Summary for 1912.' Occasionally the sands are covered by structureless deposits of sandy pebbly clay corresponding to the upper unstratified drift of the ground to the north. From the general absence of flints it is evident that the whole of the drift of this district is of western origin.

3.—London and S.E. District.

G. Barrow, District Geologist.
R. L. Sherlock, D.Sc.
H. Dewey
C. N. Bromehead, B.A. } Geologists.
R. W. Pocock, B.Sc.

In the London District the mapping has been continued in an easterly direction both on the north and south of the Thames.

Area South of the Thames.

The belt of ground lying about Croydon, West Wickham, Hayes, and Farnborough has been surveyed by Mr. Dewey; the belt farther north, bordering the Thames, by Mr. Bromehead. The mapping of the area within the one-inch Sheet 270 has now been completed.

Cretaceous.

In the southern part of the district Mr. Dewey mapped an area of Chalk-with-flints mostly belonging to high zones, but the Zone of *Holaster planus* gives a characteristic steepness to the sides of some narrow valleys near Kenley and at Biggin Hill and Cudham. This zone consists of hard nodules, often fossiliferous, embedded in soft mealy chalk. Many of the nodules appear to have been formed upon the tests of fossils such as *Micraster* and *Terebratula*;

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but in other cases hollow casts, especially of gasteropods, are seen in the hard chalk.

Pleurotomaria and *Trochus*, sponges, *Dentalium*, with *Micraster leskei* (Desm.) and *Holaster planus* (Mant.) have been collected. This assemblage is characteristic of the horizon of *Heteroceras reussianum*, which, according to Mr. G. E. Dibley,[1] occurs in the Medway Valley and also at Kenley. The mapping by Mr. Dewey serves to link up the two localities, and to show the persistence of the fauna through West Kent.

The inlier of Chalk near Lewisham was mapped by Mr. Bromehead and is referred to later (p. 30).

Eocene.

The Lower London Tertiary beds, in the area surveyed by Mr. Dewey, form an escarpment overlooking the outcrop of Chalk to the south. The escarpment is bold where the Oldhaven pebble-beds are developed, but dies away west of Croydon, where the pebble-beds either become thin or disappear. In the brick-pits between Epsom and Croydon, where there are almost complete sections from the Thanet Sand to the London Clay no pebble-beds are to be seen. Eastward from Croydon the escarpment has already been followed for some ten miles to Orpington, forming the southern limit of the picturesque plateaus of Shirley and Addington Hills and Hayes and Keston Commons.

Thanet Sand.

The Thanet Sand mapped by Mr. Dewey continues to show the expansion from west to east noted in last year's work, and at Beddington is fully 40 ft. thick.

Woolwich and Reading Beds.

The sands and clays with occasional pebble-beds, which form the Reading Series, are more or less lenticular in character as is shown by the variation in sections seen in the different pits; but at the base of the division there is a bright-green (glauconitic) sand which seems fairly persistent; it contains numerous sharks' teeth and the typical oyster (*Ostrea bellovacina*) which is occasionally aggregated to form a distinct bed.

Pebble-beds.

There is still some doubt as to the exact horizon of some pebble-beds mapped by Mr. Dewey, but for the present it is sufficient to say that they are overlain by London Clay and underlain by undoubted Reading Beds. They are dug in many places for road-metal, and can be seen to vary rapidly. In one pit the pebble-bed may be 20 ft. thick; in another, only a few hundred yards away, there may be only a few lenticles of pebbles in even-bedded sands. With few exceptions the pebbles are of Chalk-flint, black on the outside with a characteristic white spotting,

[1] *Geol. Mag.*, 1912, pp. 372–374.

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and brittle. The rare exceptions so far known are all of quartzite; these have been described by Dr. G. J. Hinde.[1] In some places the pebbles are cemented by calcareous material composed largely of oyster-shells, but these rarely, if ever, continue quite to the top of the bed. Current-bedding is often well-marked by seams of sand and sharp variations in the size of the pebbles.

In the large brick-pit at South Bromley a section nearly 50 ft. deep is exposed. In this the top 10 ft. consists of London Clay with 3 ft. of pebbles at its base, set in clay and not closely packed. Under this is about 16 ft. of even-bedded sands and clays, which rest on some 22 ft. of pebbles, the base not being exposed. Small patches of these pebbles are cemented in a siliceous matrix.

Farther north, also, Mr. Bromehead finds the same great variability in the beds below the London Clay. Thus at the northern end of Elmstead Tunnel a thick series of Woolwich loams is separated from the London Clay by some 10 ft. of sand.[2] At the southern end the total thickness of Woolwich Beds is not more than 3 ft., but between these and the London Clay are nearly 80 ft. of sandy pebble-beds (Blackheath Beds). From their general behaviour in the field it is clear that the three subdivisions between the London Clay and the Thanet Sand form essentially a single series deposited under varying conditions such as prevail near the mouth of an estuary. In this district the pebble-beds are directly overlain by the London Clay.

Structure.—Mr. Bromehead remarks that provided the Blackheath and Woolwich Beds are regarded as a unit, the structure of the ground in the part of S.E. London surveyed by him is intelligible. He notes that there are two sets of disturbances approximately at right angles. One series runs roughly south-west and north-east, and includes two faults. The Greenwich Fault has long been known; its downthrow is on the north-west, and its effect on the area mapped is to bring the Woolwich Beds against the Thanet Sands at Greenwich, the Thanet against the Chalk at St. John's, and the London Clay against the Woolwich Beds at Brockley. Farther to the south-east it has London Clay on both sides, and dies out near Dulwich.

The existence of a second fault has been proved from borings.[3] It runs from Raynes Park through Wimbledon to Herne Hill, and appears to die out near Deptford. The downthrow is again on the north-west; its effect on the outcrops is noticeable only in the neighbourhood of East Dulwich, where it brings the London Clay of Denmark Hill against the Woolwich and Reading Beds of Dulwich and Peckham. In the neighbourhood of Deptford this fault is apparently succeeded by an anticline which intersects one running through Chislehurst and Lewisham, as described below. There is some reason for supposing that the same south-west to north-east direction is followed by a synclinal flexure running through the Crystal Palace and Eltham.

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[1] *Proc. Geol. Assoc.*, vol. xi, 1890, p. 467.

[2] See 'Geology of London' (*Mem. Geol. Surv.*), vol. i, 1889, p. 226. The ten feet of sand is classed as Oldhaven and separated from the Woolwich Beds.

[3] 'Records of London Wells' (*Mem. Geol. Surv.*). 1913.

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Another and an older system runs at right angles to the one described above. Its most important member, in the area surveyed by Mr. Bromehead, is an anticline which brings the Chalk to the surface at Lewisham, and again between Bromley and Chislehurst. A second and parallel anticline is found in the Ravensbourne valley between Beckenham and Bromley, where the Thanet Sand is brought to the surface. These folds have been modified by those of the later system. Between Grove Park and Hither Green the axis of the Chislehurst anticline is depressed by the Crystal Palace syncline. It rises again towards Lewisham, and produces exposures of the Chalk on either side of the Ravensbourne. Near St. John's it has been crossed by the Greenwich Fault, immediately to the north of which the Thanet Sands are the oldest beds brought up.

At this point the Tertiary Beds disappear beneath the deposits of the Thames, but the sections proved in borings and other works show that between Deptford and Rotherhithe the strata must be involved in a dome-like structure. For it has been ascertained that to the north of New Cross an outcrop of bare Chalk exists under the gravels. The outcrop appears to be of oval shape, about one and a half miles in greatest diameter, and to be ringed round by roughly concentric outcrops of Thanet Sand and Woolwich Beds averaging about half a mile in width. The dome of Chalk was shewn on the original one-inch geological map, Sheet 1, but over a large area where the Woolwich Beds are now known to be present, only Thanet Sand was shewn, and consequently the true structure could not be made out. The dome may be regarded as the result of the intersection of the Chislehurst-Lewisham anticline with a similar fold belonging to the later south-west to north-east series.

Pleistocene.

Mr. Dewey finds that the coarse flinty detritus and rubbly chalk that so commonly occupies the dry chalk-valleys is not confined to the flat at the bottoms of these valleys, but extends to a varying height up their sides. This phenomenon is especially well seen on the east side of the Croydon valley, near Sanderstead Station, where the flinty material with a thickness of 20 ft. has long been worked in several large pits for road-metal.

Between the chalk-surface under the bottom of the valley and the top of the beds in the pits, there is a difference of level of at least 50 ft.; but there is no reason to suppose that so great a thickness of these deposits ever covered the centre of the valley; they have been accumulated as a wedge with the base resting on the flat bottom of the valley. Along the whole length of the Croydon valley this high-level material occurs exclusively on the east side, the slope on the west being bare chalk.

Similar phenomena were also noted by Mr. Dewey, but on a smaller scale, in the Epsom valley. Eight miles east of Croydon, at Greenstreet Green, near Farnborough, the same type of deposit occurs, and here also is confined to the eastern side of the valley. It was from the gravel in the base of the valley that the remains

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of Mammoth, Musk Ox, and Rhinoceros were collected which are preserved in Lord Avebury's Museum at High Elms. In a similar gravel at Hayes Station remains of Mammoth, Reindeer, Rhinoceros, and Horse were found by Dr. Male.[1]

In tracing the deposits in the centre of the dry valley at Croydon down stream to the more open Tertiary area of the Wandle valley, Mr. Dewey finds that they appear to join on to the Taplow Terrace of the Thames. The northern part of Croydon stands on a wide-spread and well-marked terrace some 20 ft. above the gravels of the dry valley. This terrace is probably the equivalent of that of Boyn Hill. No trace of it, however, has been found in the Croydon valley within the Chalk area; if it has ever existed there, it was probably swept away when the deepening to the Taplow Terrace took place.

Well-marked terrace-gravel was also observed by Mr. Dewey some 20 ft. above the dry-valley gravel, in the valley south of Hayes Common; but in this case no connection could be proved between the dry-valley gravel and the Taplow Terrace of the Tertiary area.

Area North of the Thames.

The area north of the Thames surveyed during the year includes the upper portion of the Colne valley with part of the Lea valley above Hatfield, and of the Mimram valley above Digswell. Small areas have been examined about Bushey, Oxhey Wood, and Finchley, where sections have been exposed during building operations.

On the south-east side of the Colne valley the ground rises somewhat steeply to a height of slightly over 400 ft., the rise forming part of the escarpment of the Lower Tertiary beds. On the opposite side the rise is on the whole more gradual, though the same level is eventually attained. The higher ground consists mainly of Chalk irregularly covered by Clay-with-Flints.

Cretaceous.

The Chalk mapped by Dr. Sherlock and Mr. Pocock during the year in the northern area belongs almost entirely to the Upper Chalk, but a little of the Middle Chalk crops out from below the Chalk Rock in the valleys of the Lea and Mimram as far east as Wheathampstead and Codicote Bottom respectively.

It is exceptional, however, for the Chalk to show itself through the Drift and downwash. Old pits for marling are numerous, but most of them are overgrown and comparatively little chalk is now dug for the purpose. In most sections the top of the Chalk is piped into by Clay-with-Flints or gravelly red clay derived from the Reading Beds.

The Chalk of the district around St. Albans and Hatfield contains so few fossils that no precise zonal division is possible. The greater part of it belongs to the Zone of *Micraster coranguinum*.

In the valley of the Ver, the outcrop of a hard band, closely resembling the Chalk Rock, has been traced for several miles.

[1] *Proc. Geol. Assoc.*, vol. xxi, 1909, p. 34.

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This band has been mentioned in some published well-sections and has been doubtfully referred to the Chalk Rock, but it actually occupies a horizon near the junction of the Zones of *Micraster cortestudinarium* and *M. coranguinum*.

Eocene.

READING BEDS.

In mapping the Reading Beds south-east of the Colne valley, Mr. Pocock has found that there is great difficulty in determining a base where this is in contact with or covered by the Drift. This is especially the case in the tract around Bushey and Radlett, but farther north where free from drift the line is comparatively definite.

A good exposure of the Hertfordshire Puddingstone was seen about a quarter of a mile west of Christchurch, Radlett. There a bed, about 8 ft. in thickness, presents a surface so irregular and disturbed as to suggest glacial action; upon it there lay a varying thickness of strongly contorted clay, and above that, about 15 ft. of Glacial gravel.

The large outlier of Eocene at Ayot, three miles north of Hatfield, has been mapped by Dr. Sherlock. The lower beds are white current-bedded sands with some lines of black flint-pebbles. The underlying Chalk is not visible but has been touched at widely different depths in the various pits, so that the junction with the Reading Beds must be far from a horizontal plane. The sands are remarkably variable and disturbed, either from foundering through solution of the Chalk, or by glacial action. In the easternmost pit, the sand dips off a ridge of white clay, and contains pebbles of clay derived from it. Above it there is thin-bedded sandy clay which appears to transgress over the beds below and has yielded lamellibranchs and shark's teeth. Details of these brickyard sections have been given by Mr. J. Hopkinson in 'Geology in the Field,' 1910, p. 26.

Pleistocene.

In the country north-west and south-east of the Colne valley, Mr. Pocock finds that the higher ground on both sides is more or less covered by superficial deposits which are mainly of local origin and contain no Bunter pebbles. In the latter respect they are distinguishable from the deposits at a lower level in the intervening tract.

The local material, however, has itself been derived from different sources on the opposite sides of the valley, and varies greatly in composition. On the north-western side of the valley the dominant or characteristic hard material consists of unweathered or slightly weathered chalk-flints; on the south-eastern side the dominant component is the unworn pebbles of the Reading Beds, unworn flints being rare or absent.

The high-level drifts comprise both clay-with-flints and associated pebble-gravel. These were shown in former maps by strongly contrasting colours, but there is often no correspondingly sharp contrast between the materials when seen on the ground: often it is questionable whether some portions should be called

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'Clay with abundant flints' or 'Pebble-gravel' with an extremely clayey matrix. Broadly speaking the two often appear either to pass laterally into one another, or the pebble-gravel may occur as pockets in the clay. There is no clear superposition of one above the other as in normally bedded sands and clays. A good instance of the indefiniteness of their relations was seen by Mr. Pocock in the cutting for a drain to the north of Harpenden, and by Dr. Sherlock at Gustardwood, a mile north of Wheathampstead.

The southern high-level drift shows on the whole a similar combination of clays and gravels with indefinite relationship. In some cases the clay is practically stoneless and cannot easily be distinguished, except in clear sections, from the underlying London Clay. This drift appears to cover nearly all the ground which rises above 400 ft. in this southern area. It contains no pebbles from the Bunter, and in this and other respects resembles the drift at a similar level in the adjacent area to the south and south-west, at Stanmore Common and Oxhey Wood.

In the large mass on Stanmore Common, Mr. Pocock observed that Reading pebbles form by far the greater part of the hard material, and many of these appear to have been weathered before being involved in this deposit. Vein-quartz is fairly common though much less so than at Shenley, and occurs as small pebbles, only one specimen above an inch long having been found. Other pebbles are very rare. A few of the flints have been derived directly from the Chalk, and prolonged search yielded one or two fragments of cherty rock (possibly from the Lower Greensand), one well-rounded pebble of sarsen and one fairly large block of a pebbly variety of the same.

The more gravelly material occurs in a pockety manner in the more clayey mass, and only a small portion seems to be free from clay. A few streaks and small patches of the brilliantly coloured Reading marl can be identified here and there in the deposit. At the southern end of the outcrop the clay is pale-grey in colour, and contains so few stones that it has long been worked for bricks. This clay rests directly on London Clay, the junction being fairly sharp.

An interesting feature in this birch-covered Stanmore area is the great number of more or less burnt pebbles that occur in the soil everywhere down to a depth of about one foot.

At Oxhey Wood the bulk of the material is gravelly, though unstratified. In one place a clayey patch occurs in which a block of white chert, 14 ins. long, was found.

About Shenley and North Mimms Mr. Pocock finds that small pebbles of white vein-quartz are extremely abundant, but no clue has yet been obtained as to the source from which they are derived. At Barnet, chert of Lower Greensand type is fairly abundant, while the quartz is scarcely less common than at Shenley.

DRIFT WITH BUNTER PEBBLES.

The drifts containing Bunter pebbles are broadly of two types; more or less stratified gravels, and unstratified chalky boulder-clay. Over much of the area mapped by Dr. Sherlock and Mr. Pocock the clay rests on the gravels.

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In the valley of the Colne Mr. Pocock found that the best areas for the study of these gravels are situated near Bushey town and St. Albans; here these deposits lie well down in the valley, and on the south side in particular they never extend sufficiently far up the hill-slopes to be in contact with the high-level pebbly gravel, and are clearly newer than the latter in this part of the district.

An important feature of their mode of occurrence is that the main beds are arranged in stratified order or sequence, as is specially well seen in a pit at Tyttenhanger Green. Here fairly coarse rudely-bedded gravels rest on an uneven surface of the Chalk, the bedding tending to follow the inequalities of this surface. The top of the gravel is, however, nearly horizontal, as if planed off, and a bed of brownish clay slightly chalky and about 2 ft. thick rests evenly upon it. Above this come false-bedded sands and fine gravel, which again have a fairly even top, and are succeeded by the Chalky Boulder Clay.

This bedded arrangement of the Bunter-pebble-drifts, as a series, is retained through most of the area, and leads to the development of such broad flats in the lower part of the valley, from Watford northwards towards Hatfield, that it is difficult at times to realise that the gravels are of glacial origin and not true river-gravels. It is indeed possible that the surface may have been trimmed down locally and smoothed by the river at some time, though no direct evidence of this has been obtained. That the main mass of the gravel is of Glacial age is clear, for it is overlain by Chalky Boulder Clay to the north of Bushey.[1] at Bricketwood and at Tyttenhanger as already shown.

This bedded aspect of the drifts is maintained on all the lower ground in the St. Albans district, but, on ascending the sides of the valley, contortion is met with at about 300 ft. above sea-level.

In the higher part of the Lea valley, about Cold Harbour, Mr. Pocock has found Bunter-pebble-gravels, which differ somewhat from the normal type, and which in addition are capped by laminated stoneless clay. As this valley goes right through the Chalk escarpment by the gap at Luton, it seems likely that its abnormal contents travelled by that route.

In the country north and west of Hatfield mapped by Dr. Sherlock, the drift-covered area is about 3 miles wide, the level of the ground rising away from Hatfield towards the north-west. Much of this district is flat, with a level of about 250 ft. above O.D., and here also sections show that the junctions of the Boulder Clay and Sand and Gravel are plane surfaces, more or less horizontal. On the higher ground, as at Ayot Green, where the level is about 400 ft. above O.D., or a little more, the boulder-clay, and the gravel, though containing Bunter pebbles, form a confused mass, the two rapidly replacing one another, often with nearly vertical junctions, and resting in pockets on the rocks beneath.

This distribution of the Bunter-pebble-gravels, as a belt in the lower ground between higher areas containing drifts of other compositions, reproduces the phenomena of the main Thames

[1] The information proving the point at this locality was kindly supplied by Mr. E. E. Ryder, Surveyor to the Urban District Council.

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Valley, in the Reading area. The work of Mr. Osborne White,[1] and of Mr. H. W. Monckton, has shown that the Bunter Drift travelled from north to south, through the Goring Gap, and then turned east, forming a broad belt between high-level Clay-with-flints and associated pebbly gravel (largely unbedded) on the north of the river, and a high-level flint-pebble drift on the south side. This southern drift includes a western tract containing no Greensand fragments, and an eastern part in which this material is often abundant.

Travelling eastwards this belt of Bunter-pebble-drift met the drift of the Colne valley, which had also travelled from a northerly source. The two belts meet near the confluence of the Thames and Colne valleys, in the great fan which forms such a conspicuous feature on the map.

It is noteworthy that the two southern high-level drifts bordering these belts both contain many small pebbles of white vein-quartz, and for a part of their extent some Greensand chert, as though there were some relationship between the two.

This comparison between the drift-phenomena of the Thames valley at and below Goring Gap with those of the Colne valley is rendered closer by the fact that both above the Gap and at Ayot and Codicote, where the Bunter-pebble-drifts attain a sufficient altitude, there is a local mingling of types; the Bunter pebbles occur in what is essentially pebble-gravel.

The Chalky Boulder Clay associated with the gravels varies considerably in composition in different parts of the district; about St. Albans, when unweathered it is light blue-grey in colour, the bluish tint being largely due to the presence of mesozoic clays; in some excavations about Finchley, the proportion of Chalk, especially as large pebbles, is so great that the clay is almost white when freshly dug. In both these areas, Chalk-flints are common in it, but near Broadwater, south of Stevenage, in the recent excavations along the Great Northern Railway, Chalk-pebbles abound, but flints are scarce or absent. The site is just north of the outcrop of the Chalk-with-flints, and the scarceness of flints gives one more proof that the direction for transport had no southerly element in it. When weathered the grey Chalky Boulder Clay becomes brown or reddish-brown.

The boulder-clays in the Tyttenhanger and Hill End pits contain, in addition to Bunter-pebbles, numerous fossils derived from the Oxford Clay, a few from the Lias, and others which have not yet been determined, or are too worn for identification. Carboniferous limestone and Rhaxella chert have also been obtained. Among the varied boulders obtained from the associated gravels, besides the predominant rough flints of all sizes, are:—sarsen (in large blocks), Hertfordshire Puddingstone, vein-quartz (up to 10 in.), sandstones, grits and quartzites of various kinds, including Spilsby sandstone and many of Carboniferous age; limestone, probably Silurian; various igneous rocks, mostly decomposed, including a dark basaltic rock and a paler 'felsite,' and many large rounded pebbles of varied types, probably derived from the Bunter.

[1] 'The Geology of the Country around Henley-on-Thames, etc.' (*Mem. Geol. Surv.*), 1908, pp. 78–88, and 'The Geology of the Country around Reading' (*ib.*), 1903, pp. 60–75.

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Most noticeable among these boulders are those of 'felsite.' Though usually much decomposed, a few cores have been obtained by which their origin may possibly be traced. They have been met with by Mr. Pocock at Radlett, St. Albans, Tyttenhanger and Hill End, and by Dr. Sherlock as far north as the large pits on High Heath, west of Codicote.

The north-west limit of the main mass of the Bunter-pebble-drift is defined by a line trending north-east across the Ver valley immediately north of St. Albans, passing through Sandridge, Wheathampstead, and onwards to Welwyn and Pottersheath. More or less isolated masses and patches of gravel occur north-west of this line in the valleys of the Lea and Mimram.

OLD VALLEYS.

In the St. Albans area Mr. Pocock notes that the Glacial deposits apparently mask a pre-existing valley of considerable width, with an approximately north-east and south-west trend. The north-western margin runs in a direction corresponding with a line drawn through Oaklands, Hill End, and Park Street, curving thence to the west of Bricketwood past Waterdale Farm towards Watford. East of Park Street it is completely obscured, but to the west it is continued by an outcrop of Chalk. Farther north the north-western margin has been traced by Dr. Sherlock past Oaklands by Astwick Manor to Stanborough.

In the Tyttenhanger Pit, where the deposits apparently rest on the floor of the old valley, the bedding is fairly horizontal, but at Hill End brick-pit, on the margin of the valley, they are contorted in a manner which we might expect in loose material laid down on a sloping surface.

There seems to be a deserted course of the Ver between St. Albans and Park Street. The present course of the stream lies entirely to the east of the railway from Watford to St. Albans, but the river appears at one time to have turned sharply to the west at Newbarnes Mill, following a dry valley which passes under the railway and then bends southwards and south-eastwards to Park Street.

A probable diversion of the River Maram or Mimram has also been noted by Dr. Sherlock in respect to the present loop to the south of Codicote. In pre-glacial times the river seems to have flowed about a mile further north, and there appears to be an old channel, buried in drift, under High Heath and Codicote, and joining the present channel about half a mile north-west of Welwyn.

ALLUVIUM.

The large excavations in progress for the Albert Dock Extension have been repeatedly examined by Mr. G. Barrow, who finds that although all the deposits exposed up to the present are of comparatively recent age, the sections are of particular interest from the light that they throw upon the mode of formation of the estuarine alluvium of the Thames, and upon the changes of local conditions due to the shifting of the water-channels. Two beds of drift-wood peat are exposed in the section, which in their

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relations to the alluvial deposits, and to an obliterated old stream-channel, afford some points of instructive comparison with the conditions found in coal-seams and their 'wash-outs.' Mr. Barrow has also made an extensive collection of animal and plant remains from the excavations.

(B.)—SCOTLAND.

The field-work in the Highlands was arranged in two districts as follows:—

(1) West Highland District under Mr. C. T. Clough, M.A.
(2) North and Central Highland District under Mr. L. W. Hinxman, B.A.

The Coal-field revision was also carried on in two districts.

(3) The Kilmarnock District (Ayrshire) under Mr. C. T. Clough, M.A.
(4) Paisley and South Lanarkshire District under Mr. L. W. Hinxman, B.A.

1.—West Highland District.

C. T. Clough, M.A., District Geologist.
E. B. Bailey, B.A.
E. M. Anderson, M.A., B.Sc.
G. W. Lee, D.Sc.
J. E. Richey, B.A.I.
G. V. Wilson, B.Sc.
} Geologists.

The area surveyed in Sheet 44 lies chiefly in the Island of Mull, but includes also a small tract in Kerrera and on the mainland of Argyllshire to the south-west of Oban.

Dr. G. W. Lee spent some time on palæontological work in the islands of Skye and Raasay, in one-inch map 81, and discovered an oil-shale, a report on which has already been made public.[1]

Highland Schists and Old Red Sandstone.

Kerrera, near Oban.—The geological exploration of the island of Kerrera extends back for over a hundred years, and readers desirous of becoming acquainted with it may refer to the bibliography of the Survey Memoir on 'The Geology of the Country near Oban and Dalmally,' published in 1908. One landmark in the investigation, however, calls for special notice, to wit, the discovery of fossils in the Old Red Sandstone of this locality. In 1897, Mr. Macconochie obtained plant remains and a myriapod, *Kampecaris obanensis* Peach, and in 1898 Mr. Tait found a fish, *Cephalaspis lornensis* Traquair, on the southern shore of Kerrera at a point indicated by a note on the map (Fig. 1). The fossils occur in a greenish shale with sandstone above and conglomerate below.

Mr. E. B. Bailey reports that two formations are well represented in the island, (*a*) the Easdale Slates, and (*b*) the Lower Old Red Sandstone with associated lavas. There are also numerous north-west dolerite dykes presumably of Tertiary age.

[1] 'Nature,' Oct. 9, 1913.

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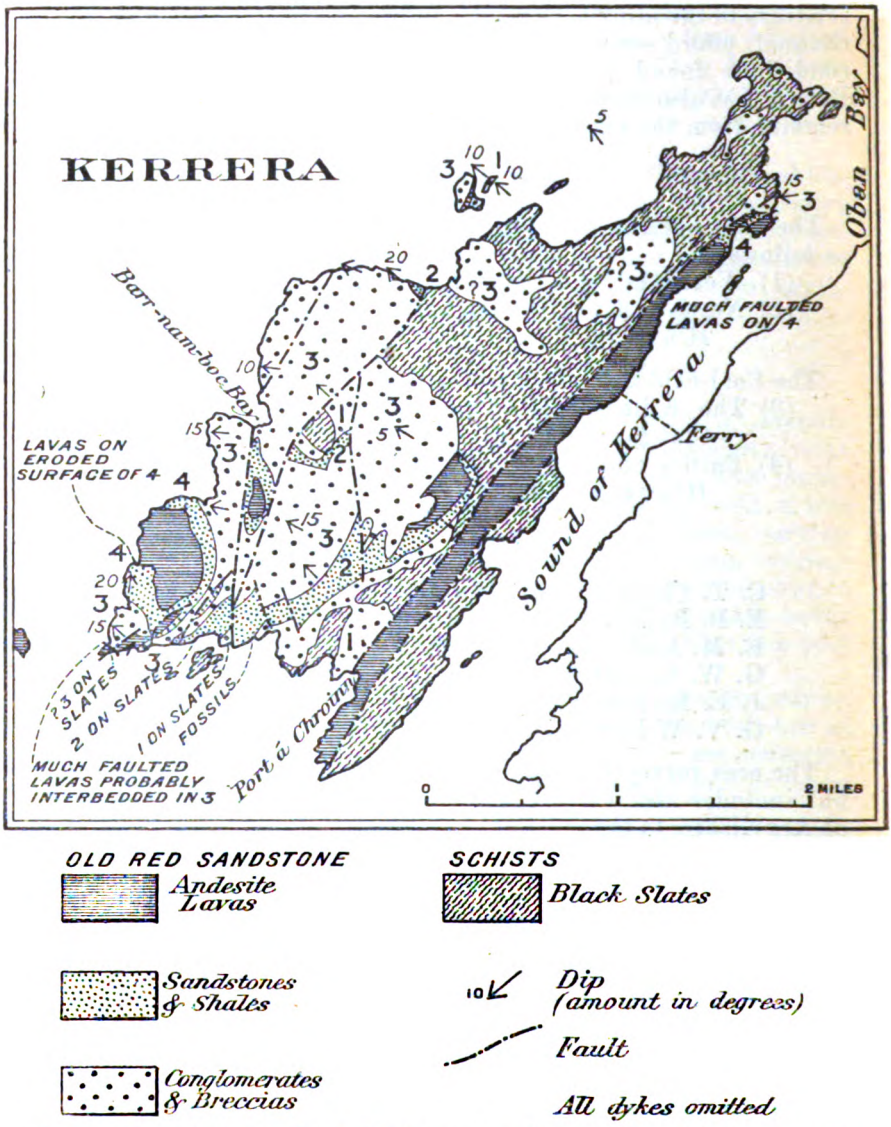

The numbers 1, 2, 3 and 4 indicate an ascending stratigraphical sequence.

FIG. 1.—SKETCH MAP OF KERRERA, NEAR OBAN.

By R. G. Symes and E. B. Bailey.

(*a*) The Kerrera development of the Easdale Slate Group (named after the island of Easdale lying several miles to the south) consists of black slates, with many thin intercalations of fairly pure black limestone, and also, in the northern and western exposures, of grey quartzose material ranging to quartzite, but not pebbly. Small-scale folding is obvious, with gentle pitches towards the south-west, in the northern part of the island, and towards the north-east, in the southern. The grade of metamorphism is low.

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(*b*) The Lower Old Red Sandstone rests with striking unconformity upon the slates. Its fullest development is, in descending order:—

Andesite lavas.
4. Sandstones.
3. Conglomerates, probably including local andesite lavas at the south-east promontory.
Andesite lava (local).
2. Sandstones sometimes with a large proportion of shales.
1. Conglomerate.

The sediments are about 300 ft. thick. It would seem that they collected upon a quite irregular surface of slate, if one may judge from the comparatively sudden disappearance of Groups 1 and 2 when followed either north or west from Port a'Chroinn. In agreement with this it is found that the bottom layer of sediment is frequently a scree-like breccia of unrolled local material.

A note on the map (Fig. 1) draws attention to a striking case of unconformity actually within the Old Red Sandstone itself. Here the lavas, overlying the sandstones of Group 4, rest in an eroded hollow at least 60 ft. deeper at the seashore than in the adjacent cliff-face.

There is no difference of type between the lower and upper conglomerates, or the lower and upper sandstones. The conglomerates consist of rounded pebbles, up to 2 ft. across, mostly of andesite, a fair number of quartzite, and a few of granite, etc.; the granite pebbles are of 'Newer Granite' type, and their occurrence in these beds has long been known. The sandstones or grits are of a purplish-grey or brown colour, with much igneous debris throughout. The matrix is not infrequently calcareous, and three thin grey limestones, with chalcedonic concretions, have been found interbedded with conglomerate on the shore a mile north of Barr-nam-Boc Bay. Grey, green and red shales are met with occasionally, generally associated with the sandstones. Bright-red sediments of any kind are rare.

The andesite lavas are all fine-grained purplish rocks, often highly vesicular, and sometimes, as in the exposures on the west coast, columnar in their central portions. Their cracks and irregular cavities are commonly filled in with sandstone, and sometimes with bedded limestone.

The map illustrates the general faulted nature of the district. A remarkable feature is a narrow band let down between trough-faults, which can be traced for four miles, though it is only a sixth of a mile across. For the most part this band consists of highly shattered andesite lavas, faulted against slates on either side. Towards the north-east, sandstones (Group 4) and conglomerates (Group 3) emerge in due order; and it is possible, with their assistance, to recognise a plexus of faults within the narrow strip. It should be noted that the trough-faults to which attention is now directed had already been traced years ago on the unfinished field-maps of the island left by the late Mr. R. G. Symes.

Mesozoic Rocks.

Loch Buie, Mull.—Mr. Wilson completed the mapping of the above district, and only at one locality were any beds found which are older than the Jurassic. This is at Frank Lockwood's Island,

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where some pale-green marly sandstones are overlain by a green conglomerate, with angular pebbles of felspathic grit and slate, in a matrix which is very like the Triassic sandstone of other parts of Mull.

About three-quarters of a mile to the south-west of Glenbyre, a small patch of Jurassic rocks consisting of limestones with *Gryphaea* at the base, and sandy beds (Pabba Shales) above, is well exposed in the cliff-section. The beds dip steeply to the west, and on their east side are thrown against Tertiary lavas, by a slightly reversed fault—the Cui'-leim fault—with a throw of about 800 ft.

In Glen Libidil an interesting patch of Jurassic rocks occurs. The beds are exposed by denudation in the centre of an anticline, and on their northern side are bounded by a fault, with a downthrow to the north of about 400 ft., which is probably a continuation of the Cui'-leim fault, though it has not been possible to trace its course through the lavas to the west of Laggan. The rocks consist of hard indurated sandy beds with *Gryphaea* and belemnites (Pabba Shales).

Islands of Skye and Raasay.—While engaged on the investigation of the Jurassic rocks of Raasay and Skye, Dr. G. W. Lee had the opportunity of making a few alterations on the old mapping, in addition to some that had already been made by Messrs. Thorneycroft and Wedd.

RHAETIC.

Dr. Lee could find no evidence of the presence of Rhaetic beds west of Rudha na Leac. Although the area mapped as Rhaetic is much obscured by slipped materials, enough is seen to show that the Trias is more probably faulted against the *Ostrea*-limestones which form the basal portion of the Lower Lias.

UPPER LIAS.

Part of the area mapped as Middle Lias, 1½ miles due east of Raasay House, was found by Messrs. Thorneycroft and Wedd to be occupied by the ironstone and the strata overlying it, which are repeated by faulting.

The areas mapped as Upper Lias east of Storab's Grave and above Druim an Aonaich belong to the base of the Estuarine Series.

ESTUARINE SERIES: OIL SHALE.

An account of the discovery of oil-shale in Skye and Raasay has appeared in 'Nature' for October 9th, 1913.

The stratigraphical position of the shale is at the very base of the Great Oolite Estuarine Series. It immediately succeeds a marine clay of Garantiana age (high in the Inferior Oolite), and it contains some of the fossils typical of the Estuarine Series:—plant-remains, Entomostraca, *Cyrena cunninghami* Forbes, and *Potamomya ? sp.*

The shale is brownish in colour, fine in grain, gives a wooden sound under the hammer, and has a brown streak. It is tough,

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and resists disintegration by weathering, a character which distinguishes it from the bituminous shales found throughout the Estuarine Series, all of which crumble into small fragments. It is as yet known to the Survey only from natural exposures, where, through weathering, it assumes a lilac or yellowish coating.

The thickness of the seam at the outcrop may be taken to be from 7 to 10 ft., but its passage into the overlying sediments is gradual.

The samples analysed for the Survey were much weathered, so that we are not yet in possession of exact data concerning the yield

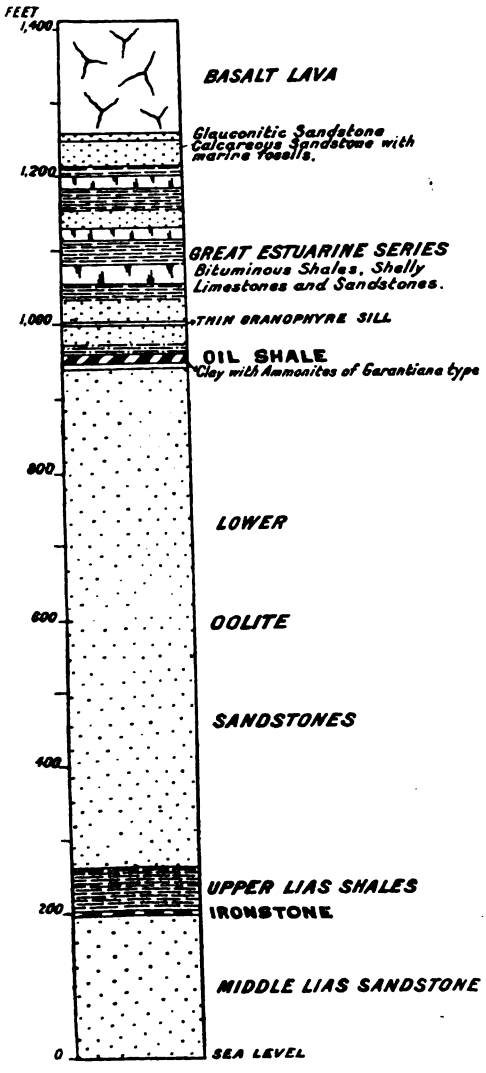

FIG. 2.—DIAGRAMMATIC SECTION ILLUSTRATING THE SEQUENCE OF THE JURASSIC ROCKS BELOW DÙN CAAN, ISLE OF RAASAY.

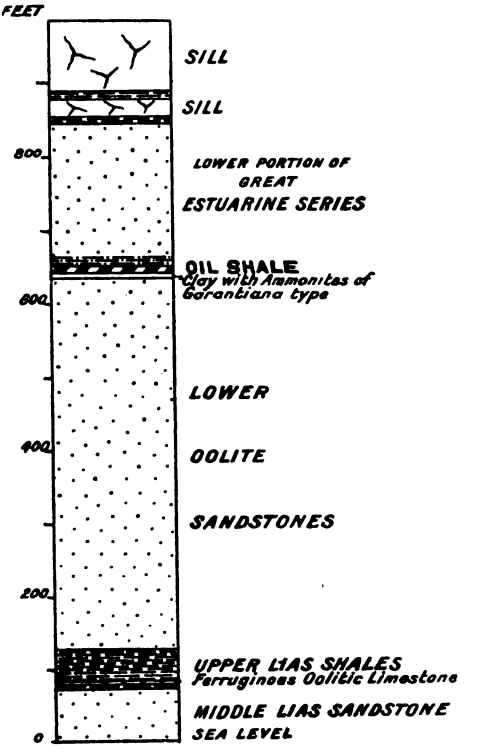

FIG. 3.—DIAGRAMMATIC SECTION ILLUSTRATING THE SEQUENCE OF THE JURASSIC ROCKS IN THE CLIFF BETWEEN HOLM AND PRINCE CHARLES'S CAVE, ISLE OF SKYE.

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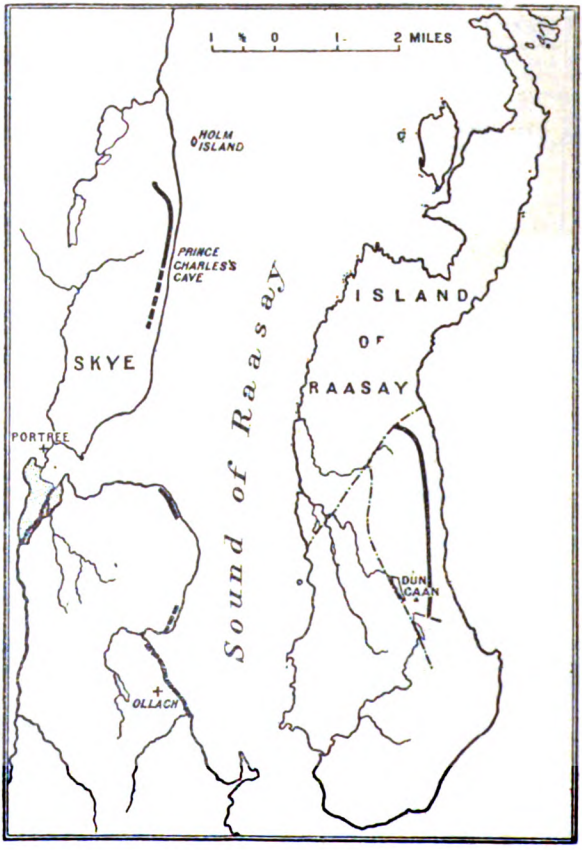
of oil and by-products from the fresh shale. That the fresh shale may be expected to yield more than weathered portions seems probable, but to what extent is not known, and it is on that that the industrial possibilities of the find depend.

A sample from the outcrop where the shale was first detected in Raasay gave 12 gallons of crude oil per ton of shale, with 6.2 lbs. of sulphate of ammonia, which is equivalent to at least 12 lbs. in a works retort.

A compound sample from the Skye coast, between Holm and Prince Charles's Cave, yielded 12.8 gallons of crude oil per ton, and 7.4 lbs. of sulphate of ammonia. Mr. D. R. Steuart, who kindly undertook these tests, states that the samples were so weathered that he did not expect to get any oil. Consequently these results indicate that the shale is worth further investigation.

Before the period of denudation which removed so much of the Scottish Jurassic rocks, the shale probably extended over a large area. Still, the portions that escaped denudation are not inconsiderable. In Raasay the field occupies an oblong area stretching from Dùn Caan northwards to the boundary fault, which



—— Oil Shale. [igneous rocks.
- - - - Oil Shale, where burnt by contact action of
—·—· Faults.

FIG. 4.—SKETCH MAP SHOWING THE OUTCROPS OF THE OIL SHALE.

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throws the Mesozoic rocks against the Torridonian. It is three miles long, with an average width of seven-eighths of a mile, which diminishes southwards. The strata are not folded, but have a dip of about 10° to the west.

In the Portree district of Skye there was once an extensive field, of which much has been destroyed by the contact action of intrusive rocks. The crop has been traced from Ollach—five miles south of Portree—to the Holm Burn—five miles north of Portree. The outcrop south of Portree shows much alteration from heat, except between the Tom cave and the Clach Dubh. North of Portree the destructive action of the intrusions is felt as far as Prince Charles's Cave, but between that point and the Holm Burn—one and a half miles farther north—the shale has escaped the action of igneous rocks. There is no inland exposure of the oil-shale horizon, which is everywhere covered by higher beds; consequently the probable extent of the field towards the west cannot be estimated. But the dip being low the shale would be within practicable reach for some distance inland. In the cliff-section between Bearreraig and Upper Tote, that is north of the point just considered, the shale-facies is replaced by a sandstone-facies.

Dr. Lee has also had an opportunity of examining the shale-horizon in the peninsula of Strathaird (one-inch map 71). There the position is beautifully exposed, but the shale is destroyed by the action of the igneous intrusions.

Tertiary Rocks.

Loch Buie, Mull.—Both near Glenbyre and on the south coast of Laggan, the base of the lavas can be seen, and in some parts of Laggan Mr. Wilson finds between the lavas and the underlying Mesozoic rocks a thin layer of Tertiary sediments. To the west of Port Ohirnie the layer is about 12 ft. thick, buff-coloured, marly and without stratification or any distinct plant-remains. This bed dies out when traced eastward, and near Glen Libidil it is replaced by a few inches of sandstone with fragments of igneous rock.

Above these Tertiary sediments comes a great thickness of lavas of which the bottom members are mostly basic in character. The latter thin down from about 800 ft. near Glenbyre to 400 ft. near Glen Libidil. Above them there is a zone of lavas of various types, mainly basalts with some andesites and mugearites, and these are succeeded by a great thickness of lavas which are chiefly andesites.

After the outpouring of the lavas and before the intrusion of the rocks to be described later, a series of folds and an important fault were developed. These folds had already been traced by Mr. Bailey in their northerly extension, and have now been mapped by Mr. Wilson through Laggan, which is the western end of the Croggan peninsula, across Loch Buie and into the Glenbyre ground towards Rossal (see Fig. 5).

They show that around the plutonic intrusions of the central part of Mull the lavas and sediments, together with the platform

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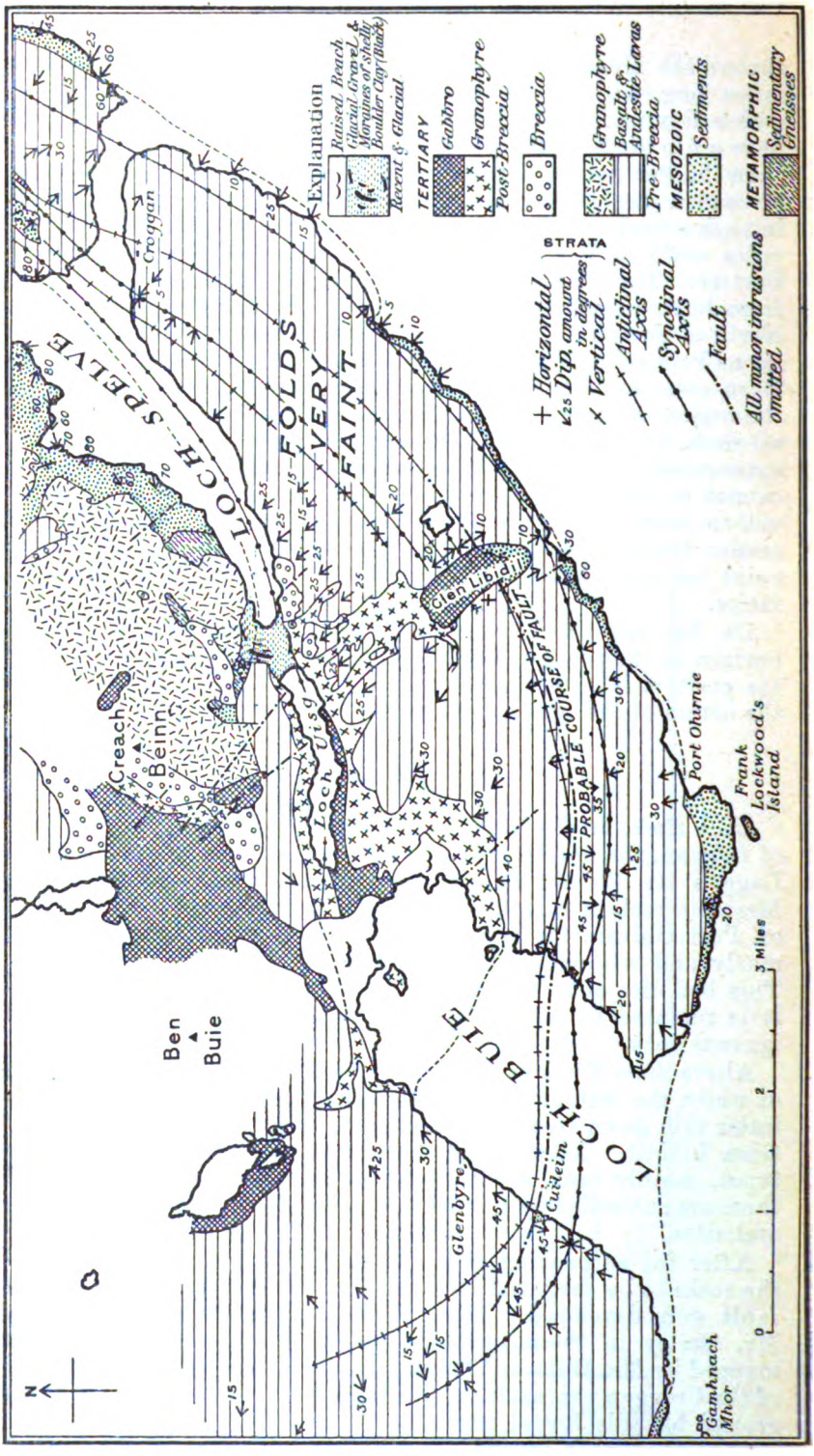

FIG. 5.—SKETCH MAP OF THE LOCH SPELVE AND LOCH BUIE DISTRICT, MULL.

By E. B. Bailey and G. V. Wilson.

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of metamorphic schists on which they rest, have been thrown into a series of folds that describe a curved arc from near Craignure to a point south of the east end of Loch Scridain, or round almost two-thirds of the interior of the island. That they should have taken this form is of great interest though it is at present premature to attempt to explain in what manner the pressures arose which occasioned it.

A great number of intrusions occur around Loch Buie, the largest being the granophyre which extends from Loch Buie along both sides of Loch Uisg and into Laggan as far as the head of Glen Libidil. This granophyre is earlier than two large gabbro masses, one of which is exposed between Loch Uisg and the sea at Loch Buie, and the other in Glen Libidil. Besides the above, many small intrusions have been noted, several of which are inclined sheets and cut the Loch Uisg granophyre. Numerous dykes were met with; the main directions are north-west and east-north-east, but in the west of Laggan a few with a nearly east-and-west direction also occur.

An interesting small volcanic neck, on the coast about 300 ft. east of Glen Libidil, consists of an outer intrusion of a coarsely crystalline basic rock full of xenoliths, with a central patch of volcanic agglomerate. The neck cuts a small east-and-west dolerite dyke and a subacid intrusion that is later than the dyke.

Mr. Wilson continued the mapping of the ground between Ben Buie and Creach Beinn, and traced the Craig and Ben Buie gabbro eastwards to the north of Creach Beinn, where it shows in a striking manner that it is later than most of the inclined sheets of this area. Several other isolated patches of gabbro in this district behave in the same way in relation to the inclined sheets.

North of Loch Scridain.—Mr. Anderson has traced the dividing line between the basalt lavas and the overlying andesites some distance to the north of Loch Scridain. Here, as in Laggan, the two groups are separated by a certain number of flows of intermediate character. North of Loch Beg the lavas dip as steeply as 35° to the south-east towards what may be a continuation of the outermost syncline shown in Fig. 5. Westwards they flatten out rapidly into the typical 'plateau' country, while the dividing features become more pronounced.

Layers of sediment up to 8 or 9 ft. in thickness occur at different horizons between the andesites. These include shales and ashes, and also a curious breccia. A shaly bed on the south side of Ben More contains traces of plant-remains, and will be searched further in the hope of obtaining a recognisable flora.

A few flows of more basic character occur high up in the andesitic series, forming the summit of Ben More. This helps to explain how Prof. Judd came to assign a higher position to the plateau-basalts than he did to the andesitic group.[1]

Mr. Anderson reports the presence near Dererach and Am Binnein of several composite sills and inclined sheets, with thin dolerite margins, and much thicker central portions of the more acid Craignure type. In each case the central intrusion is the

[1] 'The Secondary Rocks of Scotland. Second Paper. On the Ancient Volcanoes of the Highlands and the relations of their products to the Mesozoic strata.' *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 244.

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later, being chilled along its edges, while chilling is absent from the interior margins of the dolerite. Considering their thinness the basic margins are curiously regular, and it is suggested that the later rock was intruded along a median joint-plane, such as can be seen in certain thin dolerite sheets in the vicinity.

A rather massive inclined sheet of Craignure type extends from near Meall nan Uan (where it was mapped by Mr. Lightfoot) to the eastern shoulder of A'Chioch. Several other inclined sheets of acid facies, including some of the Craignure type and also spherulitic felsite, occur between this one and the summit of Ben More. As these all dip eastwards they may form outer members of the external and older ring of inclined sheets referred to as (3), (4) and (5), in last year's 'Summary' (pp. 38, 39). Mr. Bailey finds that the outer members of this ring have likewise an acid facies in the Craignure district, and also near Ben Buie.

Parallel to the massive sheet of Craignure type above referred to, and dipping in the same direction, is another thick layer, strongly resembling trachyte. It extends at least a mile to the north of Ardvergnish, and was traced by Mr. Lightfoot for $2\frac{1}{2}$ miles to the south of Kinloch. It is cut by the sheet of Craignure type, and as it follows the bedding of the lavas its relations are not yet certain.

A group of inclined sheets not hitherto described makes its appearance on A'Chioch. These are basic intrusions never more than 5 or 6 ft. in thickness, and as far as they have been traced they dip at gentle angles to the west and north-west. They are, however, very irregular, and often follow the bedding of the lavas, while certain intrusions dipping in a contrary direction seem from their character to belong to the group. They are numerous on Ben More, but die out along the strike, about a mile to the south. They will be referred to provisionally as the A'Chioch group of inclined sheets.

Mr. Richey reports that between Ben More and Loch na Keal these sheets abound. In their undulating upper surfaces and general westward dip they differ from the inner or Beinn Talaidh ring of inclined sheets, and are in fact cut by some of the latter on Beinn Fhada. They are, however, later than some of the acid sheets already mentioned as probably forming outer members of the outer ring. They are also later than various sheet-like masses of coarse dolerite, some of which are intruded in the upper Clachaig granophyre.

Mr. Anderson distinguishes dykes of more than one class to the south of Ben More. Many of these run north-north-west, and probably belong to the group which cuts all the other intrusions. Examples of this set may be seen on the shore to the west of Dererach, where marine erosion during the formation of the 25-ft. beach has left them standing out in a wall-like manner. A north-west dyke on the south-east flank of Ben More has so indurated the lavas near it that a trachytic intrusion has been unable to pierce them, but has left a vertical screen of lava on both sides of the dyke. As the trachyte itself is cut by other intrusions this proves that the north-west dykes belong to two classes in this district, as in Mr. Richey's ground to be described later.

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East-and-west dykes are also frequent, and include a good example of a composite dyke, which, like the sills and sheets, has basic margins and an acid centre.

Mr. Anderson reports that near Kilfinichen there are a number of sills and inclined sheets consisting partly of pitchstone and partly of tholeiite, similar in habit to those which are so numerous on the south side of Loch Scridain. Mr. Richey records the presence of this group to the west of Dishig, where they can be distinguished from the inclined sheets of the A'Chioch set by their greater thickness and constant inclination southwards. Most of them have black chilled edges an inch or two thick, and at least one example shows sheath-and-core structure. Some of them are cut by north-westerly dykes. The group is thus shown to extend from the south shore of the Ross of Mull to Loch na Keal.

West part of Glen More, Mull.—On p. 45 of last year's 'Summary' it was stated by Mr. Clough that a number of inclined sheets on the south side of the Corra-bheinn gabbro are accompanied by reversed faults. Further examination has shown that the appearances are probably all due to the uplift caused by the insertion of the inclined sheets.

On the southern slopes of Cruach Choireadail thin strips of a porphyritic rock, probably a rather basic andesite, with numerous felspar phenocrysts, are frequently seen, preserved between the inclined sheets which are chilled against them. Similar porphyritic rocks can be traced down almost to the floor of that part of Glen More which lies about three-quarters of a mile above Craig, and they are in this locality comparatively free from inclined sheets. These rocks frequently show irregular curved forms, often from 2 to 4 ft. in length, which have some resemblance to the 'pillows' of pillow-lavas. No concentric rows of vesicles have been observed in them, but between adjacent 'pillows' thin green or brown streaks with distinct fragmental structure have been frequently noticed, together with harder patches of a pale-grey colour that perhaps represent fine-grained silicified ash. It seems evident, therefore, that these porphyritic rocks must represent lavas. Their phenocrysts are generally rather larger than those in the andesites which come above the basaltic lavas of the Loch Buie district, and it is possible that they belong to a different group. They are sometimes associated with compact, often very vesicular dark rocks, which are also believed to be lavas. Both the porphyritic and the compact rocks bear great resemblance to rocks found by Mr. Wright on the south or inner side of the huge curving rhyolite dyke that crosses the north-west end of Loch Bà. This dyke, it may be remembered, is accompanied by a fault with a large downthrow towards the interior of the curve, and the lavas on its inner side presumably belong to a much higher horizon than those on the outer.

The porphyritic lavas of Cruach Choireadail have contributed much material to a breccia which is found over considerable areas on the same hill, but which, like the lavas, is only preserved in thin strips between the inclined sheets. A great many patches of intrusive coarse dolerite or gabbro, of earlier date than the adjacent inclined sheets, are also earlier than this breccia, and

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have given up material to it. It is often difficult to draw a sharp line between the breccia and the adjacent older rocks: for some yards before the distinct breccia is reached the older rocks are frequently crossed by innumerable cracks.

About a third of a mile west-south-west of Cruachan Dearg a small strip of breccia occurs on the Corra-bheinn gabbro, and is evidently for the most part made up of fragments of it, though it also contains small pieces of some acid igneous rock. As the Corra-bheinn gabbro is later than most of the inclined sheets that lie outside its margins, it seems to follow that this patch of breccia is later than them also.

On the lower western slopes of Ben Buie a coarse gabbro, which has a great resemblance to the Craig gabbro, but has not yet been traced up to it, has given material to an adjacent breccia. A somewhat less coarse doleritic intrusion, which covers a considerable area in this neighbourhood is, on the other hand, later than the breccia, and is chilled against it.

A coarse-grained basic plutonic mass, which is later than the Craig gabbro, and cuts off a great multitude of inclined sheets, is well seen in the crags on the west side of Glen More, about a mile above Craig. This later mass, which we will call the Glen More gabbro, has a great resemblance to the plutonic masses in Coir' a' Mhàim and Coir' an t-Seilein, which were mentioned in last year's 'Summary,' and probably has underground connections with them. Taken together, the crops of these three masses form an interrupted rather irregular curve with the concave side on the north. It was stated last year that the Coir' an t-Seilein rock varies greatly in composition, and sometimes makes a close approach to granophyre. The Glen More gabbro also varies in much the same way. In the crags on the west side of Glen More the common type has a specific gravity of about 2.86, but is traversed by several, apparently nearly horizontal, paler sheets, 3 or 4 ft. thick, of specific gravity about 2.55. These are not chilled, but have nevertheless well-defined margins. On the west side of the glen the gabbro forms two arms, one of which extends nearly to the top of Cruach Choireadail, and seems to become more acid the higher the ground on which it is exposed. The most acid types are either granophyre or felsite (at the margins). The impression given is that the change is quite gradual, but a large part of the surface is covered by blocks that are not exactly *in situ*. On the east side of the glen, pale acid types are also found some distance above the floor of the valley, but at the highest levels the rock is again considerably darker and heavier.

The Clachaig and north side of Ben More.—The large fault with the broad rhyolite or felsite dyke of Loch Bà, mentioned by Mr. Wright in previous Summaries, was not traced by him beyond Beinn nan Gabhar, but Mr. Richey now finds that it continues south and south-east past An Cruachan to the far side of the Clachaig River, and the Loch Bà dyke also reappears with it. The part of its course mapped this year, taken in conjunction with the part that was previously known, makes a rude semi-circle, and is indicated on the accompanying map (Fig. 6). The lavas and

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breccias on the inner or downthrow side, are considered to belong to a higher series than the more basic lavas on the outer, the fault appearing to continue with undiminished strength.

On An Cruachan, east of the fault and cut off against it, are plutonic rocks of variable composition. The summit of the hill is formed of lava cappings and felsites representing the margins of a granophyre that becomes gradually more basic on the lower slopes, while in the Clachaig River the rock is a variable gabbro. It is suggested that these rocks form one intrusion of the type just described by Mr. Clough, and that the gabbro of the valley on the downthrow side corresponds to an intrusion of a similar character on the ridge connecting An Cruachan and Beinn Fhada on the other side of the fault.

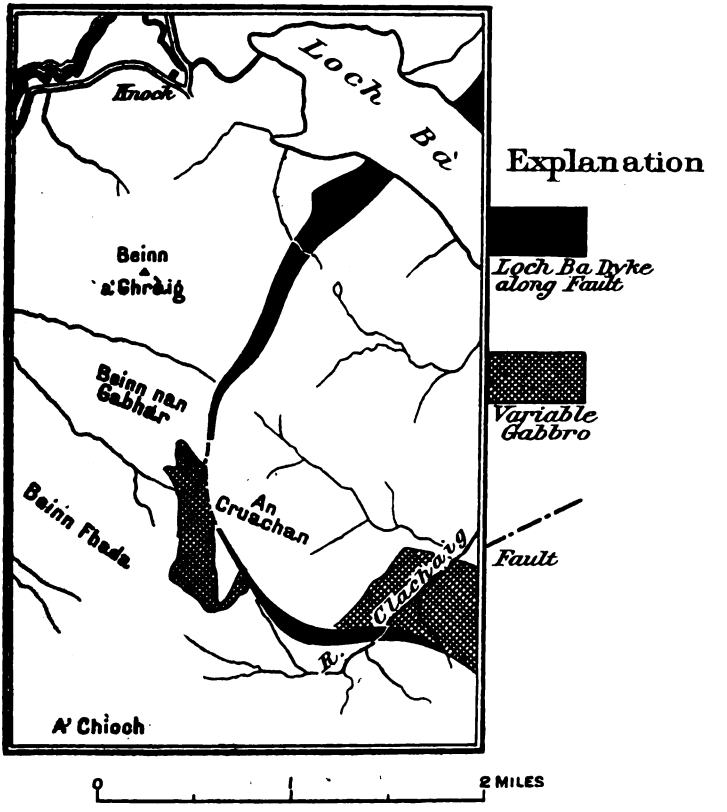

FIG. 6.—MAP TO ILLUSTRATE COURSE OF LOCH BÀ DYKE ALONG FAULT.

This latter gabbro[1] is cut by a granophyre that fills up the head of the Clachaig Valley and grades at its margins into the felsites that were mapped on Beinn Fhada last year. This granophyre is also intruded into the Corra-bheinn gabbro and separates outlying portions of it from the main mass. With the exception of

[1] 'Summary of Progress' for 1912 (*Mem. Geol. Surv.*), 1913, p. 43 and Fig. 2.

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the broad rhyolite dyke all these intrusions are cut by many inclined sheets of the Beinn Talaidh type.

A thick felsite sheet comes through to the north side of A'Chioch from the south. It is earlier than the A'Chioch sheets (p. 46) and probably belongs to the outer set of inclined sheets, some subacid examples of which have been found by Mr. Anderson on the south side of A'Chioch, where they are cut by members of the A'Chioch inclined sheets.

A belt of north-west basic dykes, many of which are of multiple habit, is exposed on the shore of Loch na Keal south-east of Knock. Microscopic examination shows that a certain number, in fact, about 30 per cent., are albitized, the minerals in the amygdules comprising epidote, garnet and secondary felspar. One of these albitized dykes is cut by an inclined sheet of Beinn Talaidh type, with a centre of granophyre, and others are cut by inclined sheets of the A'Chioch set, so that it seems probable that we have in this district two sets of north-west dykes, one of which has been altered by the Beinn a'Ghraig granophyre, that lies about three-quarters of a mile to the south-east.

Central Glen More and Loch Spelve.—Mr. Clough has drawn attention to rude pillow-structure exhibited by certain porphyritic lavas east of Craig in Glen More (p. 47). Perfectly normal pillows, with concentric arrangement of vesicles, have been noticed by Mr. Bailey in non-porphyritic lavas at various points between Loch Sguabain, in Glen More, and Coire Gorm, half way to Loch Spelve. These examples, noted respectively by Mr. Clough and Mr. Bailey, are the first recorded from the British Tertiary province.

In last year's 'Summary of Progress' (pp. 46-47, with plate), Mr. Bailey reviewed the evidence bearing upon the relations of the great Tertiary breccia of south-eastern Mull. He there showed good reason to believe that the breccia, so far as it occupies the heart of the syncline passing east of Dùn da Ghaoithe, behaves as an overlying cover and not as the infilling of a crater. This conclusion has been supported by a detailed examination of the south-western end of Loch Spelve, where the continuation of the Dùn da Ghaoithe syncline encloses an elongated outcrop of breccia (map, p. 44). On the one side, the margin of this breccia is hidden by the waters of Loch Spelve, but on the other a junction with andesite lavas is well exposed for a distance of about a mile. The andesite lavas dip at 25° towards the breccia and almost certainly pass under it. The district is one of fair relief, and includes but few intrusions, so that the conditions are favourable for accurate observation. The main difficulty arises from the fact that the lavas merge into the breccia without a sharp plane of demarcation. If Mr. Bailey is justified in his view that the Loch Spelve breccia overlies the andesite lavas, then the disintegration of the lavas at their contact with the breccia must be attributed to the effects of prolonged pre-breccia erosion. Similar disintegration is an almost constant feature wherever rocks, older than the breccia, come into conjunction with it. Accordingly it is a great advance to know of, at any rate, one instance where it can be attributed to atmospheric erosion with fair certainty.

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In the account given last year (*op. cit.* p. 47), it was pointed out that the Tertiary age of certain rocks grouped as pre-breccia granophyre was inferred merely upon petrological grounds. Mr. Bailey has now found exposures, near a little stream flowing past a cottage called Seanvaile, on the shores of Loch Spelve, which settle the question beyond doubt; a typical member of the pre-breccia granophyre complex is seen here to produce marked felspathization in Triassic sandstones with which it comes in contact.

In certain respects the problem of the breccia has become more complex than ever as a result of the year's work. For instance, Mr. Clough refers to the finding of patches of breccia later than the Corra-bheinn and Ben Buie gabbros of the Glen More district (p. 48). The breccias of these patches resemble in their characters the great breccia of south-eastern Mull, but they differ from it materially in age, for the great breccia is cut by numberless inclined sheets of a suite which, for the most part, antedates the two gabbros mentioned above.

The district now considered has furnished Mr. Bailey with three additional examples of gabbro masses merging in an upward direction into granophyre. This phenomenon is repeated so often in Central Mull (see pp. 48, 49), that it seems necessary to regard it as due to gravitational differentiation. Mr. Bailey thinks further that the evidence supports an interpretation involving liquation, rather than a separation due to the sinking of early-formed crystals. It is hoped to deal with the subject somewhat more fully next year with appropriate chemical and petrographical detail.

The variable gabbro-granophyre complexes just referred to do not behave as inclined sheets, but as great concentric dykes or, as they may be styled conveniently, ring-bosses. Such indeed seems to be a characteristic habit for plutonic rocks in Mull, though nowhere exhibited to so great advantage as in the Loch Sguabain tract of Glen More, examined during the past field-season. Mr. Wright, who first described intrusions referable to this suite, drew special attention to a curious feature which they commonly exhibit. The ring-bosses, where not in actual contact, are separated by more or less narrow strips of country rock, dyke-like in form, to which Mr. Wright has applied the designation 'screen.'[1] In the present district these screens consist in large measure of inclined sheets in addition to lavas and breccia, and thus furnish capital instances of the intersection of early inclined sheets by plutonic masses, similar to those described in last year's 'Summary of Progress' by Messrs. Clough, Wilson and Richey. Later inclined sheets are in turn found traversing the ring-bosses.

Another feature of interest is the frequency of horizontal displacement along north-westerly faults in the Loch Spelve district (map, p. 44). It thus appears that the Port Donain fault, which markedly displaces the axis of the Loch Don anticline,[2] is far from exceptional in its behaviour.

[1] W. B. Wright. 'Summary of Progress' for 1909 (*Mem. Geol. Surv.*), 1910, p. 33.

[2] E. B. Bailey. 'Summary of Progress' for 1909 (*Mem. Geol. Surv.*), 1910, p. 28.

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Pleistocene and Recent.

Loch Buie, Mull.—Mr. Wilson mapped occasional patches of the 100-ft. raised beach near Loch Buie, and the 25-ft. beach which forms a well-marked shelf and the large flats on which stand Loch Buie village and Laggan Lodge.

Between Loch Uisg and Loch Buie an interesting exposure shows about 5 ft. of stiff blue boulder-clay, with many pieces of Morvern granite, resting on a few feet of morainic gravel. The glacial striæ in Laggan indicate a general westerly direction for the ice-movement.

Loch Scridain, Mull.—The 25-ft. raised beach feature can be followed along the north shore of Loch Scridain to the head of Loch Beg, and marks the limit of certain fine gravelly deposits. North of Loch Beg there is also a trace of a higher feature at about 50 ft. above sea-level, while a still higher feature can be easily seen from a distance in certain states of illumination. The last has been followed for nearly a mile by Mr. Anderson. It lies between 160 and 170 ft. above O.D., and reappears with the same elevation on the south side of the loch. As it shows a distinct suggestion of being glaciated, it seems reasonable to connect it with the pre-glacial shore-line described by Mr. Wright[1] in Islay, Colonsay and the west coast of Mull. The highest level recorded by Mr. Wright is only 135 ft. (in Colonsay), while in the Wilderness, from 8 to 9 miles west of Loch Beg, the altitude varies from 100 to 115 ft. These figures refer, however, not to Ordnance Datum, but to high-water mark of ordinary spring tides, a fact which somewhat reduces the discrepancy.

West part of Glen More.—The floor of the glen above Craig is crossed by a series of fine terminal moraines. Mr. Clough states that the glaciers that give rise to them evidently moved down the valley in a south-west direction, and that above each of the moraines is an alluvial flat where the snout of ice which once adjoined the moraine was situated.

In the valley that extends north from the sharp bend of Glen More, about a mile and a half E.N.E. of Craig, a stiff dark grey boulder-clay is well exposed, and evidently forms the top deposit over a considerable area, in which the smooth slopes offer a great contrast to the more common morainic landscapes of the district. It is not clear in what direction the ice was moving when this boulder-clay was being formed. The valley in which the clay lies must have been outside the course of the later valley-glacier of Glen More already alluded to.

Loch na Keal, Mull.—A remarkable series of striated hollows and winding grooves has been noticed by Mr. Richey along the shores of Loch na Keal, especially between Knock and Scarisdale. These depressions have been cut in the rock irrespective of geological structure. Where, as is frequently the case, successive hollows are connected by a channel, they furnish miniature examples of rock-basins distributed along the course of a valley. The appearances suggest that the main factor in producing this effect has been running water; the hollows are almost certainly

[1] 'On a Preglacial Shoreline in the Western Isles of Scotland.' *Geol. Mag.*, 1911, *p.* 97.

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potholes; the winding channels stream-courses. Ice has been merely a modifying agent, and the striae follow the winding of the channels, as in the tortuous glacial grooves on Kelley's Island, Lake Erie, figured in Chamberlin and Salisbury's 'Geology.'[1] The clear manner in which these potholes and grooves are exhibited in the shore of Loch na Keal might suggest a marine origin, but similar though less perfect forms have been noted at altitudes up to about 1,000 ft. Probably they originated through the operation of subglacial torrents as suggested by Prof. Holmquist in the case of analogous forms observed in Scandinavia, and especially in the island of Utö, near Stockholm.[2]

Kinlochspelve.—Mr. Bailey finds that between Loch Spelve and Loch Uisg there is a high-level fan of gravel overlying shelly boulder-clay, save where the latter protrudes in well formed morainic ridges (see map, p. 44). The disposition of these ridges clearly indicates that they are the terminal moraines of a glacier which for a time occupied the site of Loch Spelve; and their material is obviously marine clay derived from the bottom of this loch and rearranged as it was pushed forward by the ice. The gravel-fan seems to have collected in a local body of standing water between a glacier in Loch Spelve and another in Loch Uisg. The surface-level of the gravel suggests a connection with the sea of the 100-ft. beach period; but if it were a purely marine accumulation one would expect to find equivalent deposits at the mouths of several streams to the east and west, where nothing of the sort occurs. If the glacial gravel and the shelly boulder-clay of the Kinlochspelve isthmus were removed, the sea would now extend freely into the deeper portion of the Loch Uisg basin.

Economics.

Many years ago excavations were made for graphite on the shore 200 to 400 yds. south-west of the mouth of Allt na Coille Mòire. The material must have been enclosed in a highly xenolithic sill of basic character, in which, Mr. Anderson states, a few small fragments of graphitic shale can still be distinguished. It seems impossible that graphite in paying quantities could be obtained here, but the locality is of interest because xenoliths of non-graphitic shale may be found in abundance surrounded by a mineral complex similar to that described in last year's 'Summary' (p. 48) from Abhuinn nan Tòrr and Rudh a'Chromain. Sapphires occur in this complex, but they are small, and less frequent than in the two localities previously known.

Mr. Bailey reports that the Easdale Slates of Kerrera were wrought about ten years ago on a very small scale, but that the attempt has been abandoned, as in most of the other islands of the West. It is possible that the thick sandstones in the Old Red Sandstone of Kerrera might be utilised for building purposes in Oban. Their outcrop is indicated on the map (p. 38), and the most promising locality is on the south coast.

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[1] Vol. iii, fig. 485, p. 349.

[2] 'The Archaean Geology of the Coast Regions of Stockholm.' Guide 15 of the International Geol. Congress, 1910, pp. 112-116.

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A large mass of clay, mixed to some extent with stones and shell-fragments, is found at Kinlochspelve, in Mull. It occurs in the form of morainic ridges, shown in Fig. 5 (p. 44) as short heavy black lines. The clay could be easily worked, as the pits would drain naturally, and it could also be readily shipped via Loch Spelve. It is present in great bulk, but the shell-fragments it contains would probably render it unfit for anything beyond the making of inferior bricks.

2.—North and Central Highland District.

L. W. Hinxman, B.A., District Geologist.
C. B. Crampton, M.B., C.M.
R. G. Carruthers
M. Macgregor, M.A., B.Sc.
C. H. Dinham, B.A.
} Geologists.

Field-work was proceeded with during 1913 in the deer-forests of Central Sutherland (Sheets 102, 108) by Messrs. Crampton, Macgregor and Dinham. A small area on the borders of Sutherland and Ross, near Oykell Bridge, in Sheet 102, was also examined by Mr. Dinham. In Inverness-shire (Sheets 54, 63) Mr. Hinxman continued the survey of the northern part of the Moor of Rannoch and the Corrour Forest, while the high ground of the Ben Alder Forest was mapped by Mr. Carruthers.

Sutherland and Ross.

Highland Metamorphic and Associated Igneous Rocks.

The area mapped by Mr. Macgregor on the eastern spurs of the Ben Klibreck massif forms the northern continuation of the Ben Armine and Loch Coire district, the geology of which has been briefly described by Dr. Crampton in recent issues of the 'Summary of Progress,' and the results of the work done in 1913 bear out the main conclusions there expressed. The low ground to the east of Ben Klibreck consists of rocks of marked Lewisian type, including quartzose, felspathic, micaceous and hornblendic gneisses and amphibolites, with later pegmatites and veins of pink acid material. While the bulk of these rocks are coarsely crystalline and granitoid in texture, others occur that resemble the semi-pelitic Moine gneisses, and are presumably of sedimentary origin. The dip is regular, and the strike, as far as this particular area is concerned, constantly N.N.E. On the low ground west of Ben Armine similar rocks occur having a N.N.W. strike. These two directions of strike are often found to obtain in the metamorphic rocks of East Sutherland, and it is believed that the one trending N.N.W. is probably the older.

Overlying these gneisses are semi-pelitic and pelitic schists of Moine facies. A belt of flaggy siliceous granulites generally intervenes between the gneisses and the pelitic rocks which form the bulk of Klibreck, but the fact that locally the pelitic schist seems to rest directly upon the gneiss suggests that the line of junction is an unconformable one. Along the Loch Coire valley

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the underlying gneisses are well exposed, and their junction with the overlying series is extremely irregular and undulating.

These rocks have been proved by Dr. Crampton to be continuous with the gneisses that form the lower part of Ben Armine, but they have not yet been followed round Ben Klibreck and their continuity with the gneisses of the Abhainn Sgeamhaidh remains to be established.[1]

The lithological determination of the rocks along the Loch Coire valley is rendered difficult by the fact that they have been subjected to increased temperature: the effects are shown by partial re-crystallisation accompanying strongly marked impregnation by later acid material.

Mr. Macgregor was also occupied for part of the summer in the survey of an area along the south-east margin of Sheet 108. This is occupied by acid and basic gneisses of Lewisian type, by pelitic and semi-pelitic metamorphic rocks of Moine facies, and by sediments of Old Red Sandstone age.

A fine rock-section is exposed in the Abhainn Sgeamhaidh and its tributary the Féith a'Chaoruinn, on the east side of the Tongue road. For half a mile from the junction of the former stream with the River Tirry there is a continuous section of flaggy siliceous quartz-biotite-granulites with a few thin bands of hornblende-schist and some veins of acid granite; the strike is north of north-west, and there is a marked development of 'rodding' in a direction west 38° north. Half a mile farther up stream the Abhainn Sgeamhaidh, turning abruptly to the north, passes through a rock-section of quite a different type to the preceding, and, together with the Féith a'Chaoruinn, flows for more than two miles over somewhat granitised acid and basic gneisses. These are well banded, and include massive acid gneiss, augen-gneiss formed by the drawing-out of pegmatite veins, coarse hornblende-gneiss, biotite and hornblende-schists and pegmatites. Good examples of *lit-par-lit* association of hornblendite and pink acid material occur, an association frequently noticed by Dr. Crampton in similar rocks in the Loch Coire area. Bands of pelitic schist and semi-pelitic granulites of Moine facies are also found.

The dip of the foliation is constant between 42° and 45°; the strike varies from north-west to north-north-west.

This series of rocks, which closely resembles the Lewisian Gneiss of some of the type-areas in the north-west Highlands, is probably faulted along its western margin against the siliceous granulites described above, but the actual junction is nowhere exposed in the ground at present surveyed. Eastwards, where exposures are few and obscure, the gneiss of Lewisian type seems to pass below the granitised complex of semi-pelitic and pelitic rocks of Creag Dubh and Creag Riabhach, and reappears on the low ground along Loch Coire and on the eastern face of Ben Armine. A similar rock-suite is found on the plateau north of Ben Klibreck. The evidence so far obtained suggests that the rocks of Lewisian type in East Sutherland form a wide platform upon which the

[1] 'Summary of Progress' for 1910, p. 42; 1911, p. 38; 1912, p. 50. (*Mem. Geol. Surv.*).

For similar phenomena observed in the Lewisian Gneiss inliers of Central Ross-shire, see 'The Geology of Central Ross-shire.' *Mem. Geol. Surv.*, 1913, pp. 30-38.

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semi-pelitic and pelitic rocks of the Moine Series of Ben Armine and Ben Klibreck rest unconformably.

The district surveyed by Mr. Dinham in Sheet 108 lies around Loch Merkland and the eastern end of Loch More. The Moine Schists which occupy the area are predominantly massive and siliceous, but contain numerous silvery micaceous bands that always exhibit strain-slip puckering. Both types of rock are in general of medium coarseness, but the siliceous schists pass locally into a conglomerate, in which the original pebbles, a quarter to one inch in diameter, can be clearly distinguished.

Near the Moine Thrust, on the north side of Loch More, the massive schists give place to thin flags, separated by planes rich in sericitic and chloritic mica, and traversed by numerous joints. Immediately above the great thrust the schists are rolled out into a fine-grained and beautifully striped pale brown rock, which passes downwards into white crushed quartzite clearly derived from the underlying Cambrian 'pipe-rock.'

The general dip is easterly, at less than 45°. Folds a hundred yards in amplitude can be traced in favourable circumstances, and the district has been subjected to some dislocation along north-west to west-north-west lines; the most important of these pass through Loch More, and on the north side of the loch shift the outcrop of the Moine Thrust at least half a mile to the east. They are continued into the Moine Schist areas, and can be traced for some distance to the east as two well marked crush-lines, occupied by burns.

The scattered igneous rocks of the district are of three types: (*a*) a handsome dark-green rock, probably a hornblendite, with quarter-inch phenocrysts of dark hornblende in an epidotic matrix; this is only found as boulders which indicate the presence of the rock in small bosses; (*b*) a finer-grained non-porphyritic basic rock, which occurs chiefly in bosses, though occasionally in thin sills; (*c*) lenticular sills of a gneissoid granite with eyes of pink felspar, not unlike certain types of the Inchbae augen-gneiss.

The small area lying north and west of Oykell Bridge surveyed by Mr. Dinham is occupied entirely by Moine Schists of more or less flaggy nature. Mullion structure is well displayed in the Oykell valley, the folds pitching to the south-east independently of the dips in the surrounding area.

Old Red Sandstone.

The occurrence of Old Red conglomerates at Loch Gaineamhach was recorded by Mr. Macgregor in last year's Report. The field-work of this season has proved the existence of a large area of conglomerate and red and chocolate-coloured grits and sandstones in Coire na Seilge, two miles south of the above-mentioned loch.

Inverness-shire.

Metamorphic Rocks.

The area surveyed by Mr. Carruthers on the west side of Loch Ericht, south of Lochericht Lodge, is entirely occupied by the

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metamorphic rocks of the Moine Series, pierced by occasional dykes and sills of pink porphyrite.

The northern and western faces of the high plateau of Ben Alder are almost wholly composed of highly folded siliceous gneisses in which certain belts can be recognised, but these are too ill-defined to be mapped out. On the northern front of the mountain a band of coarse pelitic gneiss has been traced for a short distance.

The rugged escarpments of the south-east face of the massif above Loch Ericht are traversed by innumerable veins of coarse pegmatite: one of these, south of Beinn Bheoil, is over a hundred feet broad, and can be followed in a general north-east direction for at least a mile. Farther south the pegmatites increase to such an extent that on the hill-tops above Benalder Cottage they bulk almost as largely as the country-rock.

Glaciation.

On either side of the watershed of the through valley of the Bealach Dubh, on the north side of Ben Alder, there is a remarkable assemblage of small terminal moraines. The locally derived material of which these mounds are chiefly composed shows that they were deposited during the last phase of the valley glaciation. Large masses of Moor of Rannoch granite rest upon the surface of these moraines, indicating—in the case of those on the south side of the divide—a back carry by the local glacier of the boulders left high on the mountain sides by the earlier ice-sheet as it passed eastwards through the hollow.

3.—Ayrshire.

Kilmarnock District.

C. T. Clough, M.A., District Geologist.
E. B. Bailey, B.A.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, B.A.I.
G. V. Wilson, B.Sc. } Geologists.

Most of the area revised lies in one-inch map 22, but small marginal portions of the adjoining sheets 14 and 21, on the south and west sides respectively, have also been examined. Many mining companies and proprietors have kindly given most important assistance.

Upper Old Red Sandstone.[1]

The Hills north of Ardrossan.—In this area Mr. Wilson finds that the Upper Old Red Sandstone consists mainly of red and yellow sandstones with occasional beds of conglomerate full of pebbles of white quartz. At Meikle Busbie above the red sand-

[1] The rocks described under this title were at one time taken as Carboniferous, and are so shown in the present edition of the one-inch map.

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stone there is a bed of cream-coloured cornstone about 30 ft. thick with a few cherty bands.[1]

On Caldron Hill and the ground to the west a number of sheets of a pink acid rock with porphyritic felspar-crystals are intruded into the sandstones. The sheet that forms Caldron Hill must be about 100 ft. thick in that locality, but thins out northwards and westwards.

Calciferous Sandstone Series. Carboniferous Limestone Series. Millstone Grit.

The Hills north of Ardrossan.—Above the cornstone already mentioned at the top of the Upper Old Red Sandstone, there are, immediately below the lava-flows belonging to the Calciferous Sandstone Series, some red and greyish-yellow sandy and marly beds, which contain very indistinct plant-remains, and are considered to be of Calciferous Sandstone age.[2] Mr. Wilson states that this is the only locality in the district where such beds are seen. In other places the volcanic rocks rest directly on the Upper Old Red Sandstone. These volcanic rocks are probably at least 1,000 ft. thick. The basal bed is generally a lava, but in some places an ash or breccia.

The lava-flows are mostly basic in character, and either with or without felspar phenocrysts. A few mugearitic flows have also been met with, generally near the bottom of the series. The sequence varies locally, and no definite sequence of types has yet been made out.

A large number of volcanic necks, probably most of them of Calciferous Sandstone age, have been met with. Some of these contain fragments of the pink acid rock already mentioned, embedded in a dirty dark matrix similar to the ashy material that often occurs at the base of the lava-group. At Blackshaw Hill a neck contains a central plug of dolerite. A few dolerite plugs also occur without any accompanying ashy material.

Above the lavas a variable thickness of volcanic detritus (ashy mudstones and conglomerates) comes on. In Auldmuir Burn these beds are generally red, purple or green in colour, and often contain rounded fragments of volcanic rocks similar to the underlying lavas.

Mr. Wilson examined several isolated exposures belonging to the Lower Limestone Group of the Carboniferous Limestone Series, and the beds immediately below it. Near a reservoir east of Busbie Muir, recently constructed and not shown on the one-inch map, a thin green limestone with a thin coal beneath rests almost directly on the ashy mudstones, which here are poorly represented. A few feet above this green limestone is another thin coal, and then a fossiliferous limestone which is probably the Dockra Limestone.

The Coal and Ironstone Group is only poorly exposed in this area, and is much broken by faults, but it has been found possible to fix the position of the Highfield (Index) Limestone over most of the area.

[1] John Smith, 'On a Bed of Fossil Plants, and one of Limestone with Magnesia in the Calciferous Sandstone Series, at Meikle Busbie, near Ardrossan.' *Trans. Geol. Soc. Glasgow*, vol. x, 1895, p. 129.

[2] John Smith. *Op. cit.*

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The Glen Burn[1] *and Diddup.*—Mr. Wilson measured the beds exposed at these two places as far as possible. They are represented in the following sections.

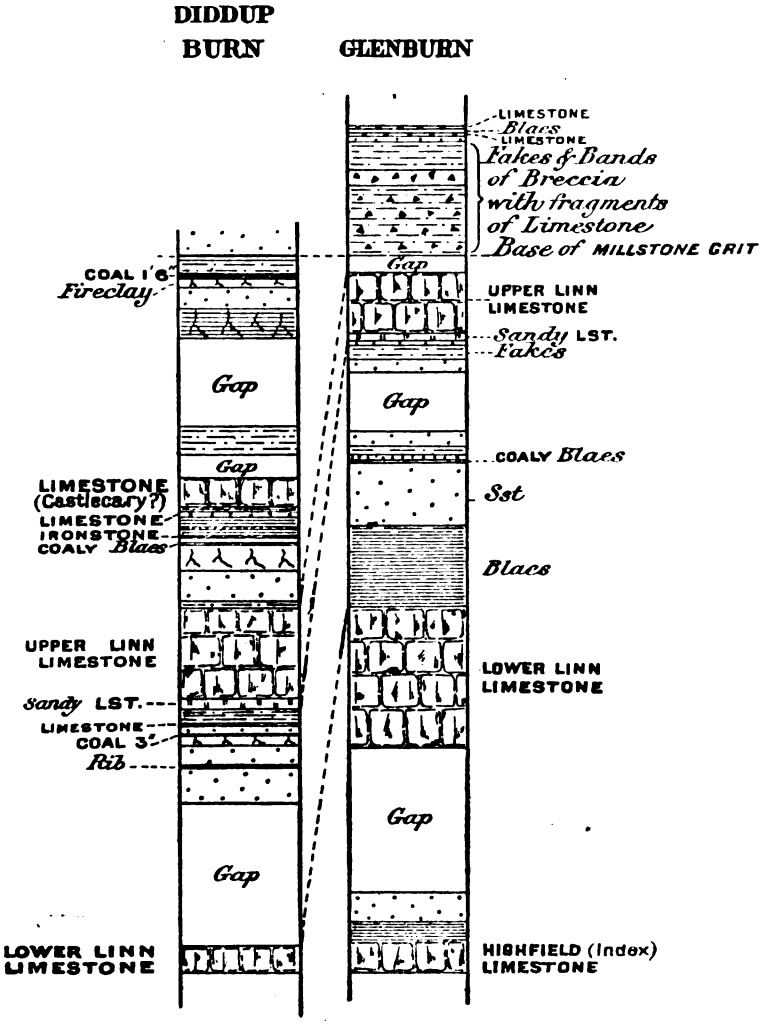

FIG. 7.—THE GLEN BURN AND DIDDUP SECTIONS.

It will be seen that in the Glen Burn a peculiar bed of breccia, which is here regarded as the base of the Millstone Grit, rests almost directly on the Upper Linn Limestone. Yet in the Diddup section, between a sandstone which is taken as the base of the Millstone Grit and the same limestone, there are about 70 ft. of strata containing a limestone-post, 6 ft. thick. This discrepancy may be due to a local unconformity at the base of the Millstone

[1] The burn that flows south-east from Knockrivoch.

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Grit, such as has been found to occur also in South Lanarkshire as described by Mr. Dinham in last year's 'Summary of Progress' (p. 61).

Dalry, Beith and Lugton.—The succession of the Lower Limestones has now been made out by Mr. Richey with Mr. Carruthers' help. The upper part of the group consists chiefly of blaes with thin limestones, and differs markedly from the lower part where there are thick limestones separated for the most part by sandstones and marls. The change takes place above the horizon of the thick limestone of Dockra quarry.

The top limestone of the group is the Calderwood Cement, while lower down, but above the Dockra Limestone, a limestone occurs in the position of the Blackhall Limestone.

The strata between the Dockra Limestone and the lavas of the Calciferous Sandstone Series vary in thickness. Where best developed they include four limestones. As they thin out the limestones disappear, the two top beds having the widest distribution, and finally only a few feet of marl separate the Dockra Limestone from the lavas. It may be supposed that the underlying lavas were in part above sea-level till the Dockra Limestone was formed, and that the lower beds have overlapped successively against an old land-surface.

The striking similarity of the beds above and below the Dockra Limestone to those above and below the Hurlet of the Glasgow basin allows us to correlate these limestones with confidence.

North of Kilmarnock.—The contemporaneous volcanic rocks believed to belong to the Millstone Grit Series are well seen in Fenwick Water, from 150 yds. north-west of Assloss House to Meiklewood. Mr. Clough estimates the total thickness to be about 100 ft. In the published maps of the Geological Survey these volcanic rocks are divided into two groups, the upper one composed of ash, and the lower of lava. So far as has been determined, however, by re-examination, the upper group consists for the most part of weathered lava. The top 20 or 30 ft. are always in a decomposed clayey condition, generally of a rather deep green colour, and contain numerous thin streaks and concretionary spots of siderite, together with occasional large lumps, as much as a foot in diameter, that are chiefly composed of this ore. In spite of the decomposition the matrix still occasionally shows crowds of minute lath-shaped felspars which indicate pronounced flow-structure. The middle part, 40 ft. or more in thickness, is also always decomposed into a soft clayey condition; the colour is usually dull-red, chocolate or brown, and concretionary spots of siderite are either absent or quite inconspicuous: an almost horizontal fluidal arrangement of small lath-shaped felspars is more often seen than in the overlying green rock, and there can be no doubt that the great bulk of the rock is lava, though here and there thin bands of fine ash have been observed. The middle part has no well-defined base, but below it comes a rock, perhaps 30 ft. thick, which is generally in a sounder harder condition, and has been quarried in various places. It often shows abundant bright-

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red spots that no doubt represent decomposed olivine. For 6 or 8 ins. at the base the rock is traversed by many thin veins of calcite nearly parallel to the base and the bedding of the underlying sediments, and it seems probable that a considerable amount of movement has taken place along the base.

The greatly decomposed character of the upper and middle parts of this group, and the concentration of siderite near the top suggest that the upper surface may have been exposed to subaerial decomposing agencies for a considerable time before the deposition of the overlying Coal Measures. It is considered probable that the concentration of iron-ore near the top may be chiefly due to the ascent of mineral solutions by capillary action from the lower rocks to a surface subject to evaporation.[1] This seems the action which is now generally called into account for the formation of the Interbasaltic ores of Antrim.[2] One of the analyses quoted subsequently (p. 69) shows a greater proportion of alumina than of silica, and this seems to indicate the presence of some bauxite.

Mr. John Smith some years ago called attention to an ironstone-bed at the top of the same group of volcanic rocks in the neighbourhood of Saltcoats, Kilwinning and Dalry,[3] and the bed next below the ironstone he described as 'fine-grained tuff, bole or laterite.'

In some coalfields near Kilmarnock, evidence collected from bores, etc., suggests that there has been a slight overlap of the Coal Measures on a land-surface formed of the pre-existing lavas, but the examination of this question is not yet completed. It may be added that similar evidence has also been obtained by Mr. Anderson in the Saltcoats and Irvine district (p. 66).

The sediments just below these volcanic rocks include a considerable thickness of fireclay, below which are two horizons of fossiliferous clayband ironstone. The upper one is about 8½ fms. below the volcanic rocks, and the lower is 11 or 12 ft. further down. In the upper horizon a Bellerophontid was first detected by Mr. Richey, and in the lower Mr. Tait has subsequently found *Lingula*. From the upper band the following fossils have now been collected:—

Schizophoria *cf.* resupinata (*Mart.*)
Edmondia sp.
Bellerophontid and other gasteropods, indeterminable.

About 22 ft. below the lower marine ironstone comes a band of calcareous blaes, about 6 ft. thick, with harder lumps and bands of dark-grey limestone. This is a richly fossiliferous marine horizon, and the upper part of it has yielded to Mr. Tait abundant specimens of *Schizodus wheeleri* (Swallow), one of the Nebraskan fossils that have lately been so often found in the Millstone Grit

[1] See Malcolm MacLaren. 'On the Origin of certain Laterites,' *Geol. Mag.*, 1906, p. 536.

[2] G. A. J. Cole. 'The Interbasaltic Rocks of North-East Ireland' (*Mem. Geol. Surv., Ireland*), 1912, pp. 1–15.

[3] 'On a Bed of Ironstone occurring in Trap Tuff in the Parishes of Stevenston, Dalry, and Kilwinning.' *Trans. Geol. Soc., Glasgow*, vol. x, 1905, p. 133.

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of the Midland Valley of Scotland. Other forms accompanying this fossil are shown in the following list:—

Lingula mytiloides *J. Sow.*
Orthotetid
Schizophoria resupinata (*Mart*
Rhynchonellid
Spirifer sp.
Productus carbonarius *de Kon.*
P. longispinus *J. Sow.* [fine-ribbed form]
P. scabriculus (*Mart.*)
P. *aff.* muricatus *Phill.*
Schizodus wheeleri (*Swallow*) [abundant]
Bellerophon sp.

Cessnock Water.—In this district Mr. E. B. Bailey has confirmed Sir Archibald Geikie's observations in regard to the following important points:—

(1) The general absence of volcanic rocks in the Calciferous Sandstone position, which latter is almost wholly occupied by sediments of the Cementstone Group, 200 ft. or more in thickness.

(2) The extreme diminution of the Carboniferous Limestone Series, with a practical disappearance of the coals, and a marked reduction of the limestones; the whole series is only about 100 ft. thick.

(3) The recognition of equivalents of the Millstone Grit group of volcanic rocks so well developed farther north.

The main results of the revision have been:—

(1) The somewhat doubtful detection of an olivine-basalt lava in the Cementstone Group near Little Sorn. Sir A. Geikie had mapped this rock in some of its exposures, but it is not clear whether he regarded it as a lava or an intrusion. That it is a lava may fairly be assumed on account of its spongy nature at the first exposures above Little Sorn Bridge. Its interstratification with cementstones is inferred from the fact that cementstones outcrop on either side; but the reading of the section is obscured by little faults.

(2) The more accurate tracing of the Lower Limestone Group, especially in the neighbourhood of Carnell.

(3) The local correlation of the various limestones exposed—a detailed correlation with outside districts has not yet been attempted.

(4) The recognition that the 'ashes' and ashy sandstones previously supposed to represent the Millstone Grit volcanic episode in this district are for the most part decomposed lavas. Additional exposures of these weathered lavas have been found in a small burn beside the railway, and in the Cessnock Water. Moreover, in the district south-west of Fiveways comparatively sound olivine-basalt or dolerite lavas have been detected in many shallow pits—all except one grassed over at the present time. These fresh lavas belong to the lower portion of the group, which is thicker near Fiveways than farther east. With the additional evidence outlined above, it has been possible to follow the outcrop of the Millstone Grit lavas across the district, thus affording an important datum-line for the exploration of the overlying Coal Measures.

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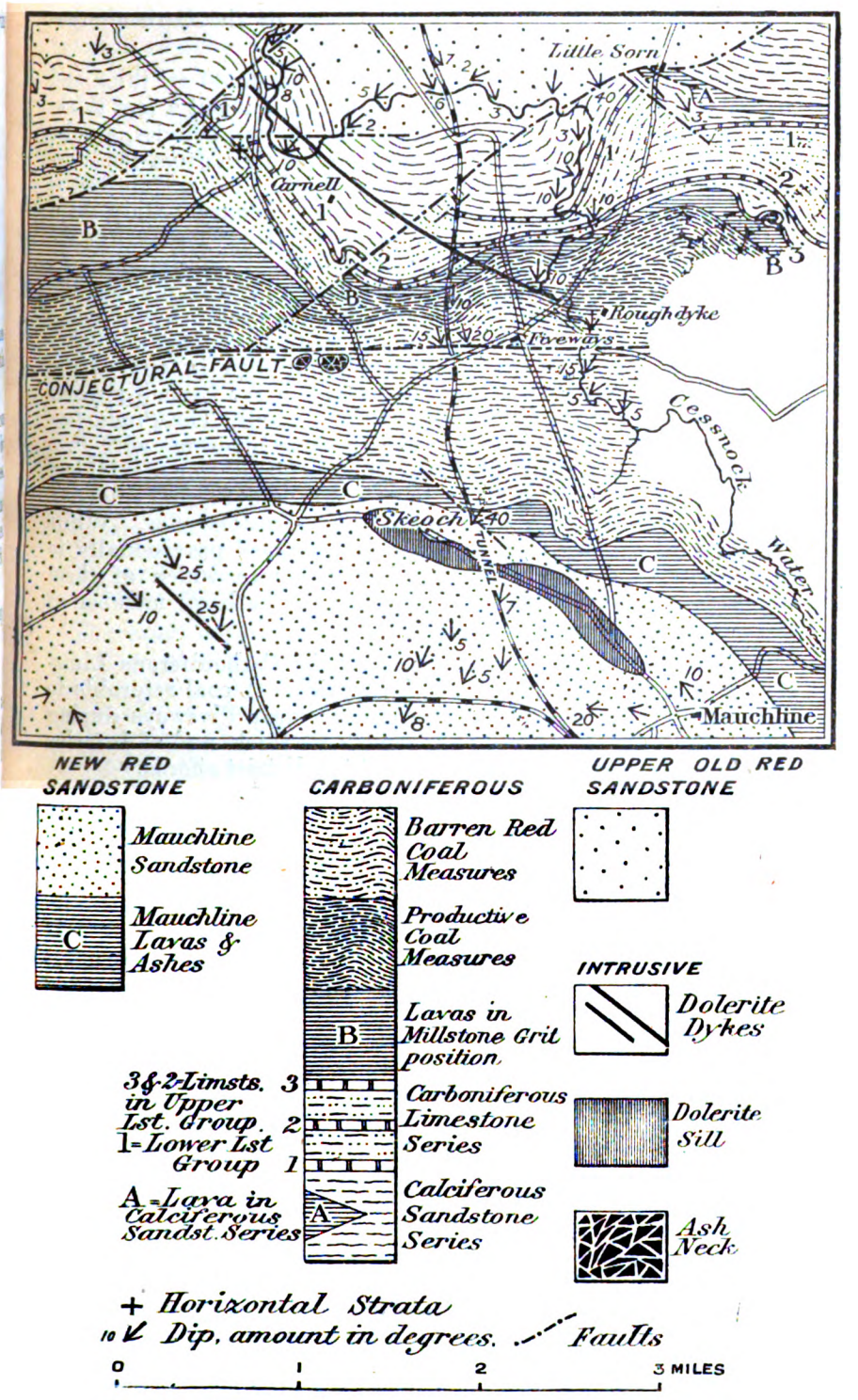

FIG. 8.—SKETCH MAP OF CESSNOCK WATER, AYRSHIRE.

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A brief description may be given here of the Carboniferous Limestone Series.

The Lower Limestone Group is about 20 or 30 ft. thick and includes three limestones. The bottom bed is about a foot thick, and is, where seen in two streams in the Carnell policies, a pale-grey encrinital limestone. A few feet separate it from the limestone which has been principally quarried. This middle bed is a marine limestone, pale, compact and concretionary. Only about 2 ft. are seen in the Carnell streams, but 4 ft. are exposed in the more westerly of the Craigie quarries outside the limits of the sketch-map (Fig. 8). The limestone passes up into sandy white fireclay, about 2 ft. thick, followed by dark-grey shales, 3 ft., and dark-grey calcareous shale teeming with *Productus* and other shells, 2 ft. The *Productus*-shale is well seen in one of the Craigie quarries a little west of the map, in the Carnell streams and in a quarry half a mile south-east of Carnell. The *Productus*-shale merges upwards into dark argillaceous limestone with *Productus*, etc. This top bed of limestone is about 4 or 5 ft. thick, and is well exposed both in the Craigie and Carnell quarries. Above are black shales with one or two ironstone ribs. While the three limestones just described are assigned provisionally to the Lower Limestone Group, it is not known which of them represents the Hurlet Limestone, taken as the basal member of the group elsewhere.

The middle Coal-bearing Division of the Carboniferous Limestone Series is only some 40 or 50 ft. thick. A coal referable to this division was wrought at the outcrop near Fiveways during the strike of 1894. It was only some 2 ft. thick, and of inferior quality, but appears to be the best that the district affords.

The Upper Limestone Group is roughly 25 ft. thick, and contains two limestone-horizons. The lower consists of about 10 ft. of dark fossiliferous shales and limestones interbanded. It is three times repeated by faulting in a small stream near the railway, and is also exposed in Cessnock Water and in a stream at the eastern margin of the map. The upper limestone is pale and concretionary, with inconspicuous marine fossils. It appears to be absent near the railway, and is only seen at the east side of the map.

Coal Measures.

Kilmarnock.—The Kilwinning Ell Coal is not seen in Fenwick Water, but is exposed, Mr. Clough states, on the west side of Craufurdland Water, about a quarter of a mile north-east of Dean Castle. A 6-in. seam of blackband ironstone, no doubt the same as that which has been worked a little further west under the name of the Plann Ironstone, is seen about 8 ft. above the Ell, and about 7 fms. below this coal comes a band of parrot shale full of *Carbonicola robusta* in excellent preservation. This musselband is also recognised in Fenwick Water, about half a mile above Dean Castle, and below it is an almost continuous section extending down to the volcanic rocks that are referred to

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the upper part of the Millstone Grit Series. The section is given below in an abbreviated form:—

	Thickness. Fms.	ft.	ins.	Depth. Fms.	ft.	ins.
Parrot Shale with *Carbonicola robusta*	0	0	6	0	0	6
Strata	1	3	4	1	3	10
Blackband Ironstone with mussels ...	0	0	4	1	4	2
Blaes	1	0	8	1	4	10
Coal	0	1	0	1	5	10
Strata	3	0	0	4	5	10
Coal	0	0	10	5	0	8
Strata	6	4	4	11	5	0
Coal	0	0	8	11	5	8
Fireclay	0	4	0	12	3	8
Sandstone	0	0	2	12	3	10
Parroty blaes with scattered *Carbonicola robusta* preserved in ironstone ...	0	0	6	12	4	4
Strata	2	0	4	14	4	8
Coal, Kilwinning Main. With two partings of dirt	0	2	9	15	1	5
Fireclay	1	4	0	16	5	5
Coal	0	1	4	17	0	9
Fireclay, etc.	0	2	1	17	2	10
Coaly fireclay	0	0	2	17	3	0
Hard buff clay with many small spots of spherosiderite	0	2	0	17	5	0
Volcanic Rocks.						

The exact nature of the buff clay with spots of spherosiderite is yet a matter of doubt. No plant-remains have so far been detected in it. The coaly clay just above this is in various adjoining localities considerably more than 2 ins. thick. Near the top of the west bank of Fenwick Water, about 140 yds. above Borland Bridge, an old trial-hole shows a very impure blackband ironstone with a thin coal near the middle: the seam is in all nearly 3 ft. thick, and rests on a hard buff clay like that noted at the bottom of the section. The Kilwinning Main has been worked in day-levels in the bank of the stream a quarter of a mile north-west of Wardneuk.

The rock-sections in the part of the Kilmarnock Water that goes through the town are interrupted by a number of obscure gaps, and are rather hard to interpret. Two coals in the west bank by the bridge called the Harriet Bridge, about half a mile N.N.E. of the railway station, are no doubt the Whistler and the Darroch (the latter the higher of the two), which in this section are separated by about 20 ft. of sandstone and fakes, though a little west of the town they come so near together that they make one working and are called the Main Coal or Finnie's Main. About 300 yds. south of the Harriet Bridge the burnt coal with an accompanying whin-float (sill) is probably the Major Coal, and two other exposures of burnt coal with an accompanying whin-float, one just above and the other 200 yds. below the High Street Bridge, are also referred to this seam.

A little south of the railway-bridge two coals are exposed in a burnt condition. The lower and thicker seam is perhaps the Tourha, though the roof is composed of sandstone instead of the hard black blaes that is usually found in this position. The upper seam may be the McNaught.

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Saltcoats and Irvine.—Mr. Anderson reports that near Saltcoats 8 or 10 fms. of strata, including the Raise Coal, separate the Kilwinning Main Coal from the underlying 'red beds' (volcanic lavas). At No. 7 pit Capringstone Colliery (north of Dreghorn), the Raise Coal is certainly absent, and lavas were found in the shaft where the Main Coal was expected. Further south lavas are almost certainly encountered some fathoms above this horizon. The evidence suggests an overlap of the higher coals against a land-surface of lavas existing at the close of Millstone Grit times.

Red measures above any workable coal occupy the centre of a syncline which runs east and west somewhat to the north of the River Irvine, and extends at least as far west as Templelands.

Cessnock Water.—There is quite a thick development of the Barren Red Coal Measures in the district included in the map (Fig. 8, p. 63), prepared by Mr. Bailey, but the Productive Coal Measures below are rather thin. The latter contain various coal seams that have been wrought locally in the past. These coals are a 5-ft. seam, worked about 1860 at Roughdyke, and the Gas and Common Coals, worked at Adamhill, a little west of the margin of the map. An almost complete section of the Roughdyke seam is visible at the present time in a cutting at a farm called Dalsangan, by the railway side. A little to the north, in a burn that passes the farm, another coal seam is exposed with a one-ft. parting of fakes, between coal 1 ft. 2 ins. above, and 10 ins. below. The district at present is being actively explored by boring. Apart from the confidential information received from this source, only one important advance has been made since the last survey. This is the abandonment of the idea of a marked unconformity at the base of the Barren Red Measures, which had been mapped at Carnell right down on to the Carboniferous Limestone Series. It is now abundantly clear that Mr. Clough was justified in criticising this interpretation as he did in 1910.[1]

New Red Sandstone.[2]

Mauchline.—It has long been known as a result of Sir Archibald Geikie's researches that the New Red Sandstone of Ayrshire is divisible into a lower volcanic, and an upper sedimentary group (Fig. 8, p. 63). The upper group consists almost wholly of sandstones made up of beautifully wind-rounded grains. Red is the prevalent colour, but white and yellowish tints are met with occasionally. The lower group consists of very basic lavas and tuffs, and it is well exposed, Mr. Bailey states, in the railway cutting. Sir Archibald Geikie has drawn attention to the prevalence of sandstone veins in these lavas at various places; the grains of the sandstone thus occurring are of the characteristic

[1] C. T. Clough. 'The Stratigraphical Relations between the Upper Carboniferous Red Barren Measures of Scotland and the Productive Coal Measures.' 'Summary of Progress' for 1909 (*Mem. Geol. Surv.*), 1910, p. 79.

[2] This term is used to include both Permian and Trias. It still appears doubtful to which of these formations the Mauchline sandstones should be referred.

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rounded wind-blown type. Mr. Tyrrell[1] has recently furnished an important contribution to the petrography of the volcanic rocks, pointing out the frequent occurrence of nepheline among them.

Intrusive Igneous Rocks.[2]

Kilmarnock.—The number of volcanic necks known in the neighbourhood of Kilmarnock has been somewhat increased, large though it previously was. All the necks noticed in this area during the original survey were considered to be of Permian age. In the ashy matrix of many of these necks Mr. Clough has noticed well-rounded clastic grains of quartz, of the type so common in the New Red Sandstone of Mauchline and Tarbolton.

In a neck in the Millstone Grit volcanic rocks a little north of (old) Rowallan Castle, the re-opening of an old quarry, has disclosed a mass of New Red Sandstone sufficiently large to have provided building stone for the whole of the new Castle, except the lintels, etc. This neck is about 8 miles north of the present outcrop of New Red Sandstone near Tarbolton (one-inch map 14), but hardly 5 miles north-east of a small outlier of this formation which appears still to exist at Thornton.[3]

The section in the quarry is now partly obscured by the tipping in of rubbish, but it is stated that the sandstone was 30 or 40 ft. thick. Most of it was white rather than red, but the white parts still exposed have the same round-grained character as the red: they may perhaps be portions that were once red but subsequently became bleached by the action of volcanic gases,[4] etc.

In the southern part of the neck considerable masses of fakes and blaes, and thin seams of coal, are also found, all in a highly disturbed condition.

Some of the loose pieces of sandstone that were formerly hewn out of the quarry show small pieces of some greatly decomposed vesicular green igneous rock, mixed with a much greater proportion of well-rounded quartz grains. The presence of these pieces probably indicates that the sandstone quarried has been formed during a period of volcanic activity. It has therefore probably come from the lower part of the New Red Sandstone. It must be noted, however, that this mass is well bedded, and must have been thoroughly consolidated at the time it dropped into the neck. This fact suggests the possibility that the neck may be even of later age than the New Red Sandstone.

Saltcoats and Irvine.—Mr. Anderson reports that near Saltcoats the main intrusive horizons in the Coal Measures occur just above the Kilwinning Main Coal, and between the Shale Coal and

[1] G. W. Tyrrell. 'The Late Palaeozoic Alkaline Igneous Rocks of the West of Scotland.' *Geol. Mag.*, 1912, p. 125.

[2] Some intrustions and volcanic necks, that seem of Calciferous Sandstone age, have been already described on p. 58.

[3] 'Explanation of Sheet 22' (*Mem. Geol. Surv.*), 1872, p. 25.

[4] The New Red Sandstone of Arran (W. Gunn, 'The Geology of North Arran, South Bute, and the Cumbraes with parts of Ayrshire.' *Mem. Geol. Surv.*, 1903, p. 101), and the Upper Old Red Sandstone (C. T. Clough, 'Geology of Cowal.' *Mem. Geol. Surv.*, 1897, p. 150), are both liable to be changed to a dirty white or yellow colour near Tertiary basaltic dykes.

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the Wee. The latter can be traced perhaps as far east as Sourlie, where, however, a larger intrusive sill occurs between the Ell and the underlying Stone Coal. North of Irvine a set of intrusions which lie below the Parrot, Turf and Wee Coals sometimes rise so as to burn or even to invade this group, while the Ladyha and Ell Coals are entirely useless. In all no fewer than 12 separate sills were met with in one boring. The Duntonknoll sill (see p. 70) is probably some distance down among these, but it cannot be identified with any confidence.

The neck which is exposed in the River Irvine a little below Montgomeryfield has been found by Mr. Anderson to contain pieces of New Red Sandstone, and a fragment of *Spirorbis*-limestone.

About half a mile south-east of this position what is probably a separate neck is being driven through in an underground road from Shewalton Colliery. The strata are found to be turned down sharply as the neck is approached, and the edge is extremely irregular. For about 10 yds. from the margin the road has been cut in a coarse agglomerate consisting entirely of sandstone, blaes, fireclay, etc., from the surrounding Coal Measures. Further in there is an admixture of igneous fragments, leading up to a fragmental rock which is much finer and entirely igneous in its materials. Altogether 140 yds. of agglomerate, with two small dyke-like intrusions, have been pierced at the time of writing.

Mauchline.—An important addition to our knowledge as the result of the revision of the 6-in. maps has been the recognition of a big dolerite-sill along the road by Skeoch Farm (Fig. 8, p. 63). This sill was previously included with the lavas, but Mr. Bailey considers that its coarse texture negatives any such suggestion. Exposures are very poor: the rock is seen at a road-side gate west of Skeoch, and was reached by digging in several grassed quarries, while fresh material, not yet examined microscopically, is abundant in the debris thrown out from the railway-tunnel. The tunnel is shown in the Survey Map (Sheet 14) as cut through lavas, but examination proves that these stop at the northern entrance, and that the interior of the tunnel traverses the overlying sandstones, save for a bricked-up interval where obviously the Skeoch sill was pierced.

Pleistocene and Recent.

Irvine.—Mr. Anderson reports that near Irvine almost continuous raised-beach deposits cover the boulder-clay, and extend inland at least as far as Dreghorn. On the banks of a small stream which enters the River Irvine from the south side near Warrix is a good exposure of a 'forest-bed' underlying a part of these deposits, but not exactly at their base. The bed is 2 ft. in thickness, and not much harder than peat, but composed largely of the branches and other remains of trees. It is possibly equivalent to the bed of 'peat' described by Mr. John Smith from the banks of the Irvine near Williamfield.[1] The latter underlies

[1] 'The Geological Position of the Irvine Whale Bed,' *Trans. Geol. Soc., Glasgow*, vol. x, 1895, p. 29.

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sand with marine shells, and likewise contains remains of trees. The overlying material may in both cases belong to the latest or 40-ft. beach of this district, and it is probable that the forest-bed marks an epoch of emergence between the latest period of subsidence and the earlier subsidences which gave rise to the higher beaches.

Economics.

Ironstone.—It has already been indicated (p. 65) that in Fenwick Water just below the lowest carbonaceous bed of the Coal Measures is a hard buff clay with numerous small spots of spherosiderite. This clay is usually only a foot or two thick, and below it comes a rather thick decomposed igneous rock which contains a considerable proportion of siderite, in streaks, spots and larger lumps (p. 60). Various observers, among whom we may specially mention Mr. J. Smith,[1] have already called attention to this or a similar rock on much the same geological horizon, under the impression that it might in the future become of economic importance. Mr. Hugh Dunn, of the Caprington and Auchlochan Coal Company, Ltd., has kindly given to Mr. Clough copies of the analyses of two samples of the iron-bearing beds of Fenwick Water. The analyses were made by Dr. E. G. Tosh, of Whitehaven, in 1868, and are given below:—

	Green Specimen.		Brown Specimen.
Protoxide Iron	34.84	...	28.72
Peroxide Iron	2.94	...	5.11
Protoxide Manganese	0.22	...	1.01
Silica	17.43	...	19.60
Alumina	19.22	...	16.82
Lime	1.43	...	2.00
Magnesia	1.45	...	0.69
Water	9.20	...	11.29
Carbonic Acid	13.23	...	14.68
Phosphoric Acid	0.04	...	0.08
Sulphuric Acid	trace	...	trace
	100.00	...	100.00
Iron per cent.	29.16	...	25.92

Dr. Tosh adds that, by calcining, the percentage of iron would be increased to about 33½ per cent. in both varieties. Mr. Clough considers it probable that each sample was somewhat carefully selected, but there is no statement to that effect accompanying the analyses.

Mr. Hugh Dunn has also given a copy of the journal of a bore (No 11 Caprington) which was put down in 1872 in a locality 167 yds. south of Todrigs, 2 miles south-west of Kilmarnock. This bore pierced the volcanic rocks of the Millstone Grit Series to some depth, and about 38 ft. below their top cut a bed, 29 ins. thick, which the journal describes as ironstone. Analyses of two samples of ironstone obtained from this bore were made by Dr. Tosh in 1872, but it is not certain that they came from the

[1] 'On a Bed of Ironstone occurring in Trap Tuff in the Parishes of Stevenston, Dalry, and Kilwinning.' *Trans. Geol. Soc., Glasgow*, vol. x, 1895, p. 133.

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bed called ironstone. The percentages of iron found in these samples differ very little from those of the samples taken from Fenwick Water, but the iron is chiefly in the form of peroxide, and, as Dr. Tosh remarked, calcination would not appreciably increase the percentages.

Osmond Stone.—Mr. Anderson states that Duntonknoll Quarries, north-east of Irvine, were for many years widely known as a source of Osmond stone, or stone for the soles of bakers' ovens. The blocks used measured 30 ins. by 30 ins. by 12 ins., and the principal requisites in rock for this purpose are—

(1) that it shall be widely enough jointed to allow the above dimensions to be attained.

(2) that it can retain heat for a long time.

(3) that it shall not chip when heated.

It must also be uniform in composition so as to avoid any differences in conducting power. The dolerite-sill at Duntonknoll satisfied these requirements, but the quarries were abandoned some years ago when iron plates came to be used in place of stone.

4.—Paisley and South Lanarkshire.

L. W. Hinxman, B.A., District Geologist.
R. G. Carruthers, M. Macgregor, M.A., B.Sc., C. H. Dinham, B.A. } Geologists.

The examination of an area of Carboniferous strata around Paisley, included in Sheet 30, and necessary for the completion of the re-survey of the Lanarkshire basin, was begun by Mr. Carruthers.

The revision of Sheet 23 was continued in the Wishaw and Hamilton coalfields by Mr. Macgregor, in the area round Larkhall by Mr. Dinham, and in the Lesmahagow district by Mr. Hinxman.

Calciferous Sandstone and Carboniferous Limestone Series.

Paisley Area.

Several points of interest have emerged during the revision of the country, south and west of Paisley, by Mr. Carruthers. In this region the sediments have a considerable vertical range, there being a full sequence of the Coal and Ironstone and Lower Limestone Groups of the Carboniferous Limestone Series (1,200 ft.), besides the underlying Calciferous division, the whole attaining a maximum thickness of 2,500 ft. and resting with marked unconformity on the lavas below.

The strata of the Limestone and Coal Groups are well known, many seams of coal and ironstone having been extensively wrought here in past times: attention may be called here to the interesting little basin at Linwood, where the Index Limestone is present with representatives of the Possil coals beneath; these strata are unknown elsewhere west of Hurlet.

The chief stratigraphical interest centres in the Calciferous Sandstone sediments south of Paisley, between the Hurlet Lime-

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stone and Coal and the lavas below. Hitherto little was known about this series beyond the fact that it consisted largely of sandstones with interbedded seams of foul coal and limestone of uncertain position and extent. From the data now available the sequence has been worked out in detail, and is given in condensed form below.

	Thickness. Fms.	ft.		Depth. Fms.	ft.
HURLET LIMESTONE AND COAL.					
Fireclay ... ... 1 to	2	0	...	2	0
White or greenish marly limestone with rootlets, etc. (brachiopods and corals at Howwood and Bridge of Weir)	3	0	...	5	0
Strata, chiefly blaes and marls ...	2	0	...	7	0
BLACKBYRE LIMESTONE with encrinites and *Producti*	0	3	...	7	3
Pale mudstone with *Naiadites* 1 to	0	2	...	7	5
Foul *Coal* ... ... 1 to	0	2	...	8	1
Strata, chiefly sandstone with a *coal* (Lady Ann) in centre	15	0	...	23	1
HOLLYBUSH LIMESTONE with large brachiopods, *Lithostrotion* and cup corals	1	4	...	24	5
Black Slate	0	1	...	25	0
Soft *Coal*	0	1	...	25	1
DIKEBAR MARLS. Strata chiefly red marls	20	0	...	45	1
'BROWN'S FIRECLAY' (worked at Ferguslie)	2	0	...	47	1
Flaggy Sandstone	5	0	...	52	1
DIKEBAR LIMESTONE and blaes, impure and irony, with brachiopods, lamellibranchs and entomostraca	0	3	...	52	4
Coals and coaly fireclay	2	0	...	54	4
Strata, chiefly sandstone	10	0	...	64	4
CASTLEHEAD UPPER COAL, foul, with blaes partings	0	4	...	65	2
Strata, chiefly sandstone	8	0	...	73	2
CASTLEHEAD LOWER COAL, foul, with blaes partings	1	2	...	74	4
Strata, chiefly sandstone	40	0	...	114	4
NEWTON COAL, worked at Newton Pit, Ferguslie	0	3	...	115	1
SANDSTONES with beds of marl and fireclay up to	80	0	...	195	1
Lavas.					

Except where locally curtailed by overlap on to the underlying lavas, the foregoing sequence holds good throughout the county south of Paisley, from Hurlet westwards to Bridge of Weir.

At Quarrelton, south of Johnstone, the strata separating the Castlehead and Dikebar coals dwindle away, and these seams run together to form one enormous mass of dirty coal with blaes and fireclay partings, the whole reaching a maximum thickness of 90 ft. Sections of the old workings show that the true thickness is more likely to be 45 ft., which has been doubled by a horizontal slip.

There are several reasons suggesting that the abnormal thickness of the great Quarrelton Coal may be due to a 'bog-slide.' The area of thick coal is restricted to a hundred acres or so, and borings show that the associated sediments were deposited on a lava slope of about 10°. Furthermore, at an old opencast mine $\frac{3}{4}$ mile south

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of Quarrelton, most of the larger debris now seen on the spoil heaps consists of a heterogeneous mixture of highly contorted coal, fireclay and ironstone; while the coal got in the mines is known to have been of a broken and 'tender' character.

An interesting feature in the tectonics of the area has been discovered. On the north side of the Clyde, an abrupt anticlinal 'ruck' was proved in working between the Old Blairdardie and Cowdenhill coal pits. This has now been traced across the river and found to run south-westwards up to the head waters of the Black Cart at Castle Semple Loch—a distance of nearly twelve miles. This remarkable line of disturbance forms a belt about 500 ft. broad, within which the strata are highly contorted and crushed, with a rude anticlinal arrangement. The strata on either side have as a rule suffered little or no displacement.[1]

Some eight years ago a 'stone mine' was driven from the Caledonia Fireclay Pit, Paisley, through the crush-belt in search of the Hurlet Coal under Paisley Racecourse. Although the seam ultimately got was thought to be the Hurlet, there are the strongest reasons for believing that it was in reality the Hollybush Limestone and Coal, and that the Hurlet Seam still lies intact under the Racecourse. Similarly the 'Hurlet' Limestone and Coal shown on the current edition of Sheet 30 as occurring in a small syncline at Paisley, is certainly the Hollybush Seam.

South Lanarkshire.

Lesmahagow District.—In the area around Lesmahagow examined by Mr. Hinxman, the extreme southern margin of the Lanarkshire coal basin is occupied by the Lower Limestone Group of the Carboniferous Limestone Series together with a narrow belt of Calciferous Sandstone, the breadth of the latter varying with the amount of overlap of the Carboniferous strata upon the underlying uneven floor of Lower Old Red Sandstone and associated igneous rocks.

Between the river Nethan at Auchenheath and the Birkwood Burn, the unconformable base lies a short distance below the white, nodular, coral limestone, the highest limestone—in this area—of the Calciferous Sandstone Series. Farther to the west the increasing overlap brings higher beds into contact with the Old Red Sandstone, till at Boghead the Main Limestone, the lowest member of the Carboniferous Limestone Series, rests almost directly upon the intrusive felsite of Dunduff.

The actual unconformable junction of the two formations is exposed in the Nethan at Garlewood and on the Teiglum Burn, 100 yds. above the Carlisle road.

A marked change in the type of sedimentation takes place immediately beneath the Main Limestone. The hard yellow sandstones and dark ferruginous shales of the Hosie sequence give place to fireclays, marls and soft marly sandstones, largely derived from the waste of volcanic rocks.

The Nethan and its tributaries afford good sections of the Lower Limestones. The Main Limestone, which has been extensively

[1] 'Geology of the Glasgow District.' *Mem. Geol. Surv.*, 1911, p. 161, and Fig. 21.

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quarried in the district, and is still worked at the Netherton Pit, increases in thickness from 7–9 ft. at Netherton to upwards of 15 ft. in the Blackwood area; it is succeeded by the encrinital limestones of the Hosie group, all of which, up to the Calderwood Cement or Top Hosie, are visible in one or other of the stream sections.

Stonehouse.—Several limestones are seen in the bed of the Avon Water at Avonholm, west of Stonehouse. These were not named during the original survey, but are now correlated by Mr. Dinham with the seams identified by Mr. Carruthers at Cot Castle, a little farther to the south, viz., the Main, Foul Hosie, Birkfield and two Kingshaw Limestones of Carluke.

A thin limy ironstone containing *Producti* and overlain by blaes with *Lingula*, is exposed in the bank of a small burn 350 yds. west-south-west of Stonehouse Manse. This probably represents the Slingstane or Wee Lingula Limestone of Carluke, though the coal usually associated with this seam in the latter district is absent from this section.

Millstone Grit.

An interesting section of Millstone Grit strata has been mapped by Mr. Macgregor in Jock's Gill, between Hallcraig and the Clyde. It consists mainly of yellow sandstone with lenticular beds of coarse pebbly grit, some beds of fire-clay and a few seams of impure coal. The rocks are faulted on the west against the Productive Coal Measures, and on the east against strata belonging to the Lower Limestone Group.

Coal Measures.

Dalserf.—The revision of the ground between Law and Dalserf has been completed by Mr. Macgregor. The centre of this area is occupied by the alluvial deposits of the Clyde, and the streams that descend to join that river from the plateau on either side afford good natural sections. The best of these, that in the Garrion Gill, was described in the 'Summary of Progress' for 1911, but Jock's Gill, Dalserf Burn, Stewart Gill and Millburn Glen also provide interesting exposures. The strata seen in Jock's Gill are probably on the horizon of the Drumgray Coals, and occupy a shallow syncline whose axis runs north-north-west; they are cut off a little north of the burn by an east-and-west fault which throws down the thick upper coals wrought at Law and Shawfield Collieries. The highest coal seen is 3 ft. 3 in. thick, but can occupy only a small area; the lower seams, of which four are exposed, vary from 12 in. to 18 in. The Dalserf burn supplies a good exposure of the Kiltongue Musselband; the section is given below for comparison with other areas:—

	ft.	in.
Blaes and ironstone balls	0	7
Black shaly blaes	0	7
Ironstone	0	0½
Black shaly blaes	0	8
Tough parrot shale	0	6
Musselband	0	9
Blaes	0	8
Coal	0	2
Fireclay and ironstone balls	2	9

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The Musselband is cut off almost immediately to the south by a large fault, and for over half a mile up stream a line of abandoned day-levels marks the outcrop of the Upper Coal, which was here 4 ft. thick. The deep gorge of Stewart Gill affords a long section wholly in the red and chocolate-coloured and often marly sandstones of the Upper Barren Measures. The lower part of Millburn Glen also gives a good section from the Ell Coal to above the Upper Coal. About 18 ft. above the latter occurs a 10-in. calcareous band crowded with 'mussel-shells.' This horizon lies 8 ft. above the Upper Coal in the Garrion burn and is again seen in the Regill burn, which joins the Dalserf burn at Auldton.

The area is traversed by a good many faults of considerable magnitude, of which those running east and west appear to be the oldest. The most important structurally are the two which extend north-westwards on either side of the Clyde, and bring up a strip of Productive Coal Measures, with possibly some Millstone Grit and Upper Limestone strata, to the surface.

Hamilton.—Mr. Macgregor has also begun the revision of the Hamilton coalfield. Since the time of the original survey of this important district in 1869, a large amount of new information has become available, necessitating considerable modification in the published maps. The ground is wholly occupied by Upper Barren Measures, and the soft, red, marly sandstones which everywhere predominate give rise to a highly characteristic type of erosion-topography. Even the smallest burns have developed a series of relatively deep and narrow cañon-like gorges. To the south-west the beds are faulted against the Lower Limestone strata of the East Kilbride district, and along the line of fault an irregular strip of Productive Coal Measures, much faulted and disturbed, intervenes between it and the Red Measures.

Larkhall.—In the district lying south and west of Larkhall, Mr. Dinham has completed the examination of the gorge of the River Avon. The low hade of certain faults introduces some peculiar features into the section, but apart from these the succession of the strata is clear enough, and extends from below the Index Limestone through the Millstone Grit to the Upper Drumgray Coal. The sequence proves throughout to be much thinner here than in its better known development on the north-east borders of the county. The character of the sequence in the two areas also shows a considerable contrast, the well-known workable seams of the Shotts and Fauldhouse district being here represented only by a few thin coals with rather inconstant 'musselband' ironstone horizons.

In the Plotcock and Quarter areas, farther to the north and west, the lowest Coal Measure horizons, as seen in the Avon gorge, have already ceased to be identifiable with any certainty, while the seams from the Lower Drumgray up to the Virtuewell, though generally recognisable, have become more or less valueless. The quality and thickness of the Drumgray and Kiltongue Coals both showed marked deterioration, while the Virtuewell, which east of the Avon around Larkhall is of good average thickness, is here affected by considerable 'wants.'

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Igneous Rocks.

The importance of the felsites and felspar-porphyries intrusive in the Lower Old Red Sandstone of the Lesmahagow area as a source of road metal of exceptional quality was pointed out in last year's 'Summary.' Another set of intrusions at a lower horizon is met with farther to the west, along the course of the Logan Water, where they range through the Downtonian Series up into the base of the Lower Old Red Sandstone. These sills are generally of a more basic type than the soda-felsites of the Lesmahagow area, and contain phenocrysts of more or less chloritised hornblende.

Thin vertical basalt-dykes pierce the sedimentary rocks and intrusive sills of the Old Red Sandstone at several localities. The trend of the dykes is usually east-and-west, but in one instance, in the Dunduff Quarry, the direction is due north-and-south.

Sills of highly altered, pale-coloured dolerite occur at two horizons between the Dross Coal and the Index Limestone along the lower course of the Birkwood Burn.

Economics.

Coal.—All the upper coals in the Hamilton district are practically exhausted. At present the Pyotshaw, the Humph, and the Blackband Seams are being worked at Udston, Earnock, Bent, and other collieries; the Virtuewell is only workable locally, and the Kiltongue coal, now widely wrought, may reach 2 ft. 9 ins., or fall as low as 1 ft. 6 ins. in thickness. The thinness and variability of the seams are compensated by the comparatively clean nature of the field.

The Hurlet Coal, underlying all the limestone measures, has up to the present time been little worked in the Paisley district; of this seam there must be some eight square miles to the north and west of Paisley. It is a soft coal, about 4 ft. thick, pyritous and of inferior quality, but still quite useful for steam-raising purposes, although inclined to run on the furnace bars. One of the most promising areas for this coal is that under Paisley racecourse, referred to on page 72.

A seam of coal in the Calciferous Sandstone Series is now being wrought at the Newton pit; it is a free-burning coal though of a 'tender' nature. Although many coals are known below the Hurlet position they are all irregular and inferior in quality.

Oil Shale.—In the Paisley area there are considerable areas of the Lillie's shale-coal still untouched; this is a laminated cannel or parrot coal, 1 to 3 ft. thick, which was at one time in great demand as an oil-producer, yielding 40 gallons of oil per ton.

Ironstone.—Clayband ironstone is still raised from the Walkingshaw Pit by Messrs. Merry and Cunninghame, but all the black-band ironstones and coals above the Hurlet position are exhausted.

Limestone.—The Main Limestone, at the base of the Carboniferous Limestone Series, is wrought at the Netherton Pit, Auchenheath, and a seam at a slightly higher horizon (perhaps the

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equivalent of the Foul Hosie of Carluke) in the Auldton Pit, Lesmahagow.

The stone in each case is of good quality, and is burnt upon the spot for building and agricultural purposes; the Auldton lime is chiefly used for plaster.

Fireclay.—Fireclays are abundant in the Calciferous sediments; at the Caledonian Pit in Paisley no less than five seams are, or have been, wrought at various horizons below the Hollybush Limestone position, while at Ferguslie, 'Brown's Fireclay' has provided a clay of first-class quality suitable for the best sanitary ware. Large areas of these fireclays are still intact: the most promising region lies between Dikebarhill, Barrhead and Hurlet, in which all the Paisley and Ferguslie seams can be got, although as yet nothing is known as to their quality. In addition, there should be other clays between the Hollybush and Hurlet Limestone: the strata are gently inclined, relatively free from faults, and two railways cross the district.

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III.—PETROGRAPHICAL WORK.

(1.)—England and Wales.

Most of the petrographical work has been in connection with the surveying in progress in North Wales and the Midlands.

A fairly large suite of rocks has been examined from the Lower Palæozoic areas of Denbighshire and Flintshire (Sheets 121, 137). These rocks form a soda-rich series which includes soda-rhyolites, soda-trachytes, keratophyres and corresponding pyroclastic rocks.

Some beautiful zeolitic minerals have been collected by Mr. King from veins in the albitized dolerite of Hendre Quarry, Glyn-Ceiriog, Denbighshire. They are mainly pectolite, in botryoidal masses with radial structure, and apophylite in small colourless prisms with well-developed basal planes. Other minerals are represented, including a yellowish secondary mica, as yet undetermined, which often coats the masses of pectolite.

In the Warwickshire and South Staffordshire District the sedimentary rocks are still receiving attention and a large collection from the Post-Cambrian intrusive masses in the neighbourhood of Nuneaton has been made. Dr. Thomas has investigated the field-relations of the interesting dioritic and granophyric rocks there displayed, and is engaged on a detailed study of their petrography.

Dr. Gibson has collected and sections have been prepared of a number of doleritic and basaltic rocks which are associated with the Carboniferous rocks of South Staffordshire.

In the South Wales District, Dr. Thomas has reported upon a series of pebbles and also upon the finer material from the Cosheston Series of the Old Red Sandstone. The pebbles are mostly rhyolites, keratophyres and soda-porphyries. The finer material is rich in detrital garnets which are exceedingly minute, pink in colour, and are perfectly idiomorphic. Garnets, zircon and tourmaline are present to the exclusion of other heavy minerals. The garnets are such as could be derived from chloritic mica-schists, and he concludes that, in view of the distribution and stratigraphical relations of the Old Red Sandstone, the only possibly source of the detrital garnets lay to the west-south-west of the present land area.

A series of specimens from a boring in the Island of Bermuda has been submitted to the Petrographical Department by the Colonial Office for examination. It is interesting to be able to record, from beneath the detrital-coral-rock that forms the island, a variety of igneous rocks which include melilite basalts and other rocks of alkaline and sub-alkaline characters.

The following experiments with orthoclase from Glass mine, Roche, Cornwall, have been made by Mr. Hallimond.

Small pieces of the felspar bounded by cleavages were put in platinum basins in hydrofluoric acid of the following strength:—

1. Concentrated.
2. Approx. 1 of concentrated acid to 2 of water.
3. ,, 1 ,, ,, 10 ,,

At room temperature 1 was attacked rapidly at first with rise of temperature, 2 and 3 remained cool.

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After 100 hours the pieces from 1 were put in cold water to remove acid and allowed to dry in the air. A crust readily broke away, but the felspar within was apparently unaltered.

Under the microscope the crust could be seen to consist chiefly of isotropic grains, often in cubes or cubo-octahedra, with a refractive index below that of olive oil, with a few spindle-shaped pieces of similar index but moderate birefringence. It was soluble with difficulty in cold water but almost completely in hot. It therefore consisted of potassium silicofluoride, K_2SiF_6.

After 7 days 2 and 3 were treated in the same way and gave the same result. Particles of unaltered felspar were found in the residues, but no other birefringent material, they were largely soluble and the residue from boiling water consisted of angular pieces of felspar. No material resembling kaolinite was found.

Some washed china-clay was put in 1 : 10 acid for 2 days. The liquid was then filtered off and evaporated, leaving a considerable gelatinous residue. This dried to a white powder which completely dissolved again. A drop of the solution on balsam deposited steep rhombohedra, R.I. below balsam and optically negative. The compound is readily soluble in water.

It is possible that the spindle-shaped pieces in the residue from strong acid are the remains of crystals of this substance.

Some pieces of felspar were put in 1 : 10 acid for 18 hours and the liquid evaporated. A considerable residue was obtained. This was redissolved and a drop allowed to crystallise, when rod-shaped isotropic cystals formed in a gelatinous film. No crystals of the alumina-compound were seen, but it is generally described as occurring in an indeterminate form.

It seems clear that: 1. The chief product of the reaction of HF on orthoclase is K_2SiF_6 the Al dissolving; 2. Kaolin is soluble in 1 : 10 HF.

(2.)—Scotland.

The petrographical work done in the Department was carried on mainly in connection with the survey of the Island of Mull and the Ayrshire coalfield. The work on the Tertiary igneous rocks of Mull is of the greatest interest, and many of the results of the petrographical study of these rocks will be found incorporated in the field-descriptions given on earlier pages. In order to maintain a close connection between the field-work and microscopical investigations Dr. Thomas spent some weeks in Mull during the past year.

Another sapphire-bearing sill has been discovered in Mull by Mr. Anderson. The xenoliths which carry the sapphire are identical in appearance to those from the Nuns' Pass, Carsaig, mentioned last year, and contain the same minerals, namely pale-blue sapphire, pink sillimanite, dark-green spinel and basic plagioclase felspar.

The dark-green spinel from the xenoliths of the Nuns' Pass has been separated in a pure state from the rock and analysed. The analysis shows that in composition it lies between hercynite and pleonaste (p. 81).

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An analysis of an anorthite-spinel-corundum xenolith is given on page 81.

Mr. McLintock, since his transference to the Royal Scottish Museum, has continued his work on the minerals of the metamorphosed Tertiary lavas on the N.E. slope of An Gearna, Mull, where the lavas come within the influence of a large intrusion of granophyre.

The uniaxial augite mentioned is last year's 'Summary of Progress' as being characteristic of the Inninmore type of intrusion has been separated from the rock by Mr. Hallimond and analysed by Mr. Radley (p. 81). Mr. Hallimond has recently communicated an account of its optical properties to the Mineralogical Society of London. The mineral is peculiar in consisting almost entirely of magnesium-iron silicate, being practically non-aluminous, and in having the composition of hypersthene.

Analyses have been made of scolecite and a pale epidote collected by Mr. McLintock in the work referred to above. The epidote is a variety rich in lime and relatively poor in iron; it occurs as radiating bundles of elongated crystals, sometimes green, sometimes pink and occasionally passing from one colour to the other in the same crystal.

The igneous rocks of Ayrshire have been collected from extensively and are undergoing petrographical investigation.

Dr. Flett has been engaged on the petrography of the schists and gneisses of Sutherlandshire in connection with the survey of Sheets 102, 108, and 109, and has written a petrographical account of the igneous rocks from Sheet 74 for the forthcoming memoir.

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IV.—CHEMICAL WORK.

During the past year the work on the composition and properties of certain clays was completed by Dr. Pollard, before his retirement.

Ten complete rock analyses have been done in the laboratory, one of these analyses being undertaken to determine the value of the rock as an ore of aluminium, and another, to find out if the rock would be suitable as an ore of iron or as a flux for other iron ores.

Four minerals have also been analysed, and estimations of water in four rocks have been made.

Mr. Hallimond has made an investigation on the action of hydrofluoric acid, of various strengths, on orthoclase in the laboratory (p. 77).

15753. Lab. No. 393. Phonolitic *Biotite-trachyte*, from an intrusive mass at Rudh'an t-Sean-Chaisteil, 4 miles S. of Tobermory, Mull, Sheet 44. The rock is fine-grained compact, grey and non-porphyritic. Composed of a plexus of oligoclase laths with subordinate orthoclase and anorthoclase; contains deep-brown biotite and a fair quantity of analcite.

15550. Lab. No. 394. Fine-grained *Augite-granophyre*. Craignure Bay, on shore 50 yds. N.N.W. of Manse, Mull, Sheet 44. Composed mainly of quartz and orthoclase in granophyric relationship, albite and acicular crystals of augite.

Lab. No. 395. *Tertiary sediment*. South side of Port nan Ban, about 1 mile S. of Loch Don, Mull, Sheet 44. The alumina-content is too low to make the rock of value as an ore of aluminium.

Slice No. ...	15753.	15550.	—
Lab. No. ...	393.	394.	395.
SiO_2 ...	60·13	71·30	39·26
TiO_2 ...	·73	·58	1·33
Al_2O_3 ...	16·53	11·24	27·34
Fe_2O_3 ...	2·86	1·80	1·57
Cr_2O_3 ...	—	—	trace.
FeO ...	2·55	2·84	17·18
MnO ...	·46	·31	·13
(CoNi)O ...	nt. fd.	nt. fd.	·04
BaO ...	·11	·07	nt. fd.
CaO ...	1·61	1·56	·74
MgO ...	1·20	1·61	·34
K_2O ...	3·99	4·66	2·05
Na_2O ...	8·06	3·44	1·08
Li_2O ...	trace.	?trace.	nt. fd.
H_2O at 105° C. ...	·55	·39	1·44
H_2O above „ ...	·97	1·04	7·20
P_2O_5 ...	·57	·22	·34
CO_2 ...	—	—	—
FeS_2 ...	nt. fd.	nt. fd.	nt. fd.
Total ...	100·32	100·06	100·04

ANAL. E. G. RADLEY.

16612. Lab. No. 396. *Xenolith* in basic sill. Nuns' Pass, Carsaig, Mull, Sheet 44. Contains basic plagioclase, sillimanite, sapphire and spinel.

Lab. No. 397. Dark-green spinel (*hercynite-pleonaste*) separated from the above.

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Slice No. ...	16612.	—	—
Lab. No. ...	396.	397.	397 re-calculated.
			Less SiO_2, TiO_2 and H_2O.
SiO_2	38·67	·77	—
TiO_2	·90	·50	—
Al_2O_3	37·27	60·84	61·70
Fe_2O_3	2·78	4·26	4·32
FeO	5·07	24·00	24·34
MnO	·17	·15	·15
(CoNi)O	nt. fd.	nt. fd.	—
CaO	4·65	·36	·36
MgO	2·35	9·37	9·50
K_2O	3·01	—	—
Na_2O	3·63	—	—
Li_2O	nt. fd.	—	—
H_2O at 105° C. ...	·22	nt. fd.	—
H_2O above ,, ...	1·63	·14	—
Total ...	100·35	100·39	100·37
Sp. Gr. at 20° C. ...	2·91	3·837	

ANAL. E. G. RADLEY.

15990. Lab. No. 402. *Uniaxial augite from intrusion of Inninmore type.* 3-16th of a mile S.W. of Trig. Sta. on N. end of Beinn an Lochain, S.W. of Pennyghael, Mull, Sheet 44.

Lab. No. 403. *Scolecite* from amygdaloidal cavity in metamorphosed Tertiary lavas. N.E. slope of An Gearna, Mull, Sheet 44.

Lab. No. 404. Pink *epidote*, from same locality as above.

Slice No. ...	15990.	—.	—
Lab. No. ...	402.	403.	404.
SiO_2	49·72	46·10	38 69
TiO_2	·85	nt. fd.	·12
Al_2O_3	·90	25·05	28·54
Fe_2O_3	1·72	·55	6·87
FeO	27·77	—	·22
MnO	·98	nt. fd.	·29
(CoNi)O	nt. fd.	nt. fd.	nt. fd.
CaO	3·80	14·17	23·78
MgO	12·69	·32	·49
K_2O	·12	·03	·03
Na_2O	·23	trace.	trace.
Li_2O	trace.	nt. fd.	trace.
H_2O at 105° C.	·08	·13	·09
H_2O above	1·27	13·78	·99
Total ...	100·13	100·13	100 21
Sp. Gr. ...	at 17° C. 3·44	at 14° C. 2·285	at 12·8°C. 3·488

ANAL. E. G. RADLEY.

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The difference between the inner and outer portions of the pitchstone-tholeiite sills was thought to be due to the variation in water-content. With this in view the following estimations of the contained water have been made.

17243. Lab. No. 417. *Pitchstone-tholeiite*, glassy inner portion. 2,200 ft. N.N.E. from cairn on Mullach Glac an t-Sneachda, Mull, Sheet 44.

17244. Lab. No. 418. Stony portion of above.

17245. Lab. No. 419. *Pitchstone-tholeiite*, glassy inner portion. 3,000 ft. S.E. from cairn on Mullach Glac an t-Sneachda, Mull, Sheet 44.

17246. Lab. No. 420. Stony portion of above.

Slice No.	17243.	17244.	17245.	17246.
Lab. No.	417.	418.	419.	420.
H_2O at 105° C.	·45	1·34	·38	1·64
H_2O above ,, ...	2·38	1·56	2·44	·93

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9628. Lab. No. 398. *Orthoclase-olivine-basalt*. N.W. side of Cruach Ard-dhuine, 3 miles S.S.W. of Taynuilt, Argyll, Sheet 45.

17059. Lab. No. 405. Fine-grained impure ferruginous limestone from the Carboniferous rocks of Burn Anne, S. of Hillhouse, Sheet 22.

16810. Lab. No. 406. *Tholeiite* of Brunton type. Tertiary dyke, Sheet 52. Composed of small clots of augite and acicular crystals of plagioclase with interstitial dark-brown glass.

Slice No. ...	9628.	17059.	16810.
Lab. No. ...	398.	405.	406.
SiO_2	49·86	19·00	51·53
TiO_2	1·06	·34	1·53
Al_2O_3	16·33	2·24	11·05
Fe_2O_3	3·62	5·07	2·73
Cr_2O_3	trace.	—	—
FeO	4·34	—*	10·98
MnO	·40	·40	·45
(CoNi)O	nt. fd.	nt. fd.	nt. fd.
BaO	·10	nt. fd.	nt. fd.
CaO	6·47	23·82	9·68
MgO	7·80	11·53	5·21
K_2O	2·10	trace.	·86
Na_2O	3·42	·97	3·48
Li_2O	trace.	trace.	trace.
H_2O at 105° C.	1·25	·32	·71
H_2O above ,, ...	2·77	2·03	1·26
P_2O_5	·54	·10	·22
FeS_2	nt. fd.	·58	·26
CO_2	·23	33·41	·08
C	—	·34	—
Total ...	100·29	100·15	100·07

* All Fe has been calculated as Fe_2O_3, except the FeS_2, owing to the presence of Carbon.

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The following analyses have been made of rocks collected by Mr. Watt in Aberdeenshire and presented by him to the Geological Survey:—

Lab. No. 399. Corvichen Qy., Huntly, Aberdeenshire.—The rock is intrusive into crystalline schists and bytownite-norite. Megascopically a slight foliation is visible. The essential constituents are quartz, microcline, andesine, oligoclase, and biotite. Less common are orthoclase and muscovite, while garnet, chlorite, apatite, and zircon are also present.

Lab. No. 400. Ordiquhill Qy., Huntly, Aberdeenshire.—The rock is intrusive into the bytownite-norite. Garnet, quartz, orthoclase, and biotite with granitic structure. In addition, oligoclase, andesine, chlorite, and muscovite occur, while the accessory minerals are magnetite, pyrites, apatite, zircon, sphene, indicolite, and monazite.

16816. Lab. No. 401. Cuternach, Huntly, Aberdeenshire. Consists of about 55 per cent. of cordierite, with hypersthene, red biotite, and labradorite. The accessory minerals are spinel, pyrites, magnetite, and zircon.

Slice No. ...	—	—	16816.
Lab. No. ...	399.	400.	401.
SiO_2	72·30	58·22	48·00
TiO_2	·37	·96	·99
Al_2O_3	12·91	19·60	24·74
Fe_2O_3	·59	·59	·18
Cr_2O_3	nt. fd.	nt. fd.	·21
V_2O_3	nt. fd.	nt. fd.	trace.
FeO	2·04	5·19	11·03
MnO	·10	·19	·24
(CoNi)O	nt. fd.	nt. fd.	nt. fd.
BaO	·03	·04	·05
CaO	1·95	3·37	·99
MgO	·82	1·02	9·94
K_2O	4·63	5·83	1·47
Na_2O	3·68	3·64	·84
Li_2O	nt. fd.	nt. fd.	trace.
H_2O at 105° C.	·03	·14	·06
H_2O above „	·55	·84	·97
P_2O_5	·10	·58	·06
FeS_2	nt. fd.	nt. fd.	·59
Total ...	100·10	100·21	100·36

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V.—PALÆONTOLOGICAL WORK.

(1.)—England and Wales.

During the year the resources of the Palæontological Department have been chiefly employed in dealing with the specimens added to the collections, for the most part in connection with current Survey work. Mr. Allen and Mr. Pringle have named series of fossils from the Cambrian, Silurian, Carboniferous, Triassic, Cretaceous and Tertiary rocks, and, as usual, many specimens have been examined and reported on by specialists who are not members of the staff. The results of these investigations will be utilised in the respective sheet-memoirs, and no points of such special scientific interest have arisen as to call for notice in this report.

In the Memoir on 'The Country around Merthyr Tydfil' (Sheet 231), published in 1904, reference was made to the fossils which occur in shales in the Millstone Grit, below the Farewell Rock. A further suite has been obtained by Dr. W. Gibson from the puddle-trench of Hirwain Reservoir (Rhigos). The following is a list of the species as determined by Mr. Pringle; the specimens are in the Survey Collection [W.G. 752-796]:—

Lingula mytiloides *J. Sow*
Orbiculoidea nitida (*Phill.*)
Productus *cf.* anthrax *Hind*
Amusium concentricum ? *Hind*
Posidoniella laevis (*Brown*)
,, sulcata *Hind*
,, sp.
Pterinopecten papyraceus (*J. Sow.*)
Nucula gibbosa *Flem*
Nuculana attenuata (*Flem.*)
,, sp.
Sanguinolites occidentalis (*Meek and Hayden*)
Schizodus wheeleri (*Swallow*)
Euphemus urei (*Flem.*)
,, sp.
Gastrioceras carbonarium ? (*v. Buch*)
Glyphioceras sp.

The occurrence of *Sanguinolites occidentalis* and *Schizodus wheeleri* is of considerable interest. These two forms have hitherto not been recorded from the Millstone Grit of South Wales, but have been found in corresponding strata in Scotland which, as shown by Dr. Wheelton Hind,[1] contain an assemblage of fossils closely similar to the lamellibranch-fauna of the Coal Measures of Nebraska and Illinois.

Since his retirement, early in 1912, Dr. Ivor Thomas has prepared for publication a substantial instalment of the monograph on the British Carboniferous *Producti* upon which he was engaged while a member of the Survey staff. This work, destined for publication in quarto form as one of the palæontological

[1] W. Hind. 'On the Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland.' *Trans. Roy. Soc., Edinb.*, vol. xlvi, part 2, pp. 331-359, 1908.

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Memoirs of the Geological Survey, has been edited and sent to press. The descriptive section of this first part, though dealing only with the pustulose and fimbriate species, forms a unit in itself. The introductory matter treats more comprehensively of the whole subject, comprising sections on the history of the study and on the morphology, evolution, classification and nomenclature of these forms. Dr. Thomas seeks to express some of the facts which point to the independence of genetic lines among these brachiopods by the introduction of new names for groups to which he assigns generic value. A few of the specimens to be figured in this work have been kindly presented to the Museum by Prof. T. F. Sibly, Dr. Wheelton Hind and Mr. J. A. Douglas.

The donations received during the year are recorded on pages 90–92. They include a series of fossils zonally collected from the Chalk of Surrey by W. Wright, Esq., F.G.S.; a suite of specimens of Upper Kimmeridgian age ('Portlandien' of Continental authors), from the old Sub-Wealden Boring, near Battle, the gift of the Public Library, Museums, and Fine Art Galleries, Brighton; and a collection of Ordovician fossils from North Anglesey, presented by Dr. C. A. Matley.

Items of interest among the fossils acquired by purchase are two skulls and a paddle of *Ichthyosaurus* from the Lower Lias and a series of Upper Jurassic Mollusca accurately zoned and localised: also the Clarkson Collection of choice Liassic ammonites from the Whitby district, obtained more than 50 years ago and raised to importance by the studies of Martin Simpson.

The following specimens in the Museum have been figured and described during the year:—

In the Palæontographical Society's Volume for the Year 1912. (Published 1913.)

British Graptolites, Part IX.

By Miss G. L. Elles, Sc.D., and Miss E. M. R. Wood, D.Sc.

Monograptus priodon (*Bronn.*), pl. xlii. fig. 2a, and text-figs. 282a, p. 419, 282c, p. 420.
,, distans (*Portlock*), pl. xliii, figs. 6a, b, p. 433.
,, halli (*Barrande*), pl. xliv, fig. 8f, and text-fig. 305a, p. 444.
,, lobiferus (*M'Coy*), pl. xlv, fig. 1e, and text-figs. 308a, b, p. 449.
,, runcinatus *Lapworth*, pl. xlv, figs. 2f, g, and text-fig. 309b, p. 450.
,, undulatus *E. and W.*, pl. xlv, fig. 5, and text-fig. 295, p. 432.
,, nodifer *Törnquist*, pl. xlvi, figs. 2a-d, and text-fig. 313b, p. 455.
,, clingani (*Carruthers*), pl. xlvi, fig. 11f, p. 463.
,, convolutus (*Hisinger*), pl. xlvii, fig. 1a, and text-fig. 324b, p. 468.
,, decipiens *Törnquist*, pl. xlvii, fig. 3b, and text-fig. 325a, p. 469.
,, triangulatus (*Harkness*), pl. xlvii, figs. 4a, e, and text-figs. 327a-c, p. 471.
,, ,, *var.* major *E. and W.*, pl. xlvii, fig. 5c, and text-fig. 328b, p. 472.
,, raitzhainiensis (*Eisel*), pl. xlviii, figs. 3a, c, and text-figs. 329a, b, p. 473.
,, spiralis (*Geinitz*), pl. xlviii, fig. 7d, p. 475.

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Monograptus communis (*Lapworth*), pl. xlix, fig. 1b, and text-fig. 336a, p. 481.
,, involutus (*Lapworth*), pl. xlix, fig. 4c. p. 478.
,, *cf.* elongatus *Törnquist*, pl. xlix, figs. 5b, c, p. 486.
,, sedgwicki (*Portlock*), text-fig. 304c, p. 442.
,, millepeda (*M'Coy*), text-figs. 323a, c, p. 465.

Cretaceous Lamellibranchia of England, Vol. II., Part IX.

By Mr. Henry Woods, M.A.

Ostrea vesiculosa (*J. Sow.*), pl. lv, figs. 11-14, pl. lvi, fig. 1, p. 374.
,, canaliculata (*J. Sow.*), pl. lvi, fig. 2, p. 375.
,, incurva *Nilsson*, pl. lix, fig. 12, p. 388.
,, boucheroni *Coquand*, pl. lx, fig. 8, p. 391.
,, diluviana *Linnaeus*, text-figs. 100-103, p. 348.
,, ,, text-figs. 120, 121, p. 350.
,, ,, text-fig. 123, p. 353.
,, vesicularis *Lamarck*, text-figs. 143-145, p. 367 (2 specimens).
Exogyra tuberculifera *Koch and Dunker*, pl. lxi, figs. 9-11, p. 404.
,, sinuata (*J. Sow.*), text-figs. 208, 209, p. 402 (1 specimen).
,, conica (*J. Sow.*), text-figs. 238-240, p. 412 (2 specimens).
,, digitata (*J. Sow.*), text-figs. 251, 252, p. 418.
Cyprina meyeri *Woods*, pl. lxii, fig. 3, p. 427.

British Cambrian Trilobites, Part IV.

By Mr. Philip Lake, M.A.

Sphaerophthalmus alatus (*Boeck*), pl. viii, figs. 1, 2, 5, p. 74.
,, major *Lake*, pl. viii, fig. 7, p. 77.
Ctenopyge bisulcata (*Phillips*), pl. viii, figs. 16-18, pl. ix, figs. 1, 2, p. 81.
,, pecten (*Salter*), pl. ix, figs. 8, 9, pl. x, figs. 1, 3, 4, 6, p. 85.

In the Quarterly Journal of the Geological Society, Vol. LXIX.

By Mr. Stanley Smith, B.A., M.Sc.

Aulophyllum sp., text-figs. 1a, b, p. 58 (2 specimens).

By Dr. A. M. Davies, A.R.C.S.

Obolella ? *aff.* salteri *Holl*, text-figs. 3a, b, p. 331 (2 specimens).

In the Philosophical Transactions of the Royal Society of London, Series B, Vol. CCIV.

The Evolution of the Cretaceous Asteroidea.

By Mr. W. K. Spencer, B.A.

Calliderma (Tylaster) jurensis (*Muenster*), pl. xii, figs. 20, 21, p. 127.
Procidaster grandis *Spencer*, pl. xiii, figs. 28, 29, p. 140.
Stauranderaster pistilliferus *Forbes*, described pp. 135, 136.

In the Transactions of the Royal Society of Edinburgh, Vol. XLIX., Part II. (No. 6).

Caradocian Cystidea from Girvan.

By Dr. F. A. Bather, M.A., F.R.S.

Pleurocystis anglica (*Jaekel*), pl. v, fig. 61, and text-fig. 78, p. 476.
,, rugeri (*Salter*), pl. v, figs. 57, 58, and text-fig. 69, p. 463.

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(2.)—Scotland.

The fossils obtained during the year, 4,392 in number, are partly from the Carboniferous areas of Central Scotland and from the Old Red Sandstone of Inverness-shire, and partly from the Islands of Raasay and Skye, where a special collection was made in order to establish the palæontological sequence of the Mesozoic rocks of that district.

The points of interest arising in connection with the Old Red Sandstone and Carboniferous materials will be mentioned in the respective sheet-memoirs, and need not be referred to here.

The fauna from the Liassic and Oolitic rocks of Raasay was collected by Mr. D. Tait. It is very rich and proves Raasay one of the finest fields for the palæontologist, rivalling, if not surpassing the classic areas of Yorkshire and Dorset.

The leading zonal fossils, namely the brachiopods and the cephalopods, are now being examined by Mr. S. S. Buckman, and the other groups have been determined by Dr. G. W. Lee.

From a preliminary examination of the materials sent him, Mr. Buckman has been able to make a few general remarks, which, though liable to minor alterations, may be quoted here.

The brachiopods of the Jurassic rocks of the British Isles have been long and minutely studied, and yet the fauna from Raasay shows many new forms of exceptional interest. There is in the Charmouthian by far the largest *Rhynchonella* of the *rimosa*-group yet known, and it is a new species which presents features of much interest to the evolutionist. There is in the Domerian a whole series of massive Rhynchonellids apparently connecting the *tetrahedra*-group and the *lineata*-group. These forms from Raasay are larger than anything yet found in the British Domerian, and, apart from their proportions, they are of exceptional interest as new additions to the Domerian fauna.

The distribution of the ammonites also presents noteworthy features: the *raricostatus*- and *armatus*-series are remarkably well represented by many species. There is an exceptional opportunity here for studying the Raricostatus Beds. In most parts of England these beds are poorly developed, and in many cases their fauna is found remanié in the Armatus Beds. In Raasay these Raricostatus Beds are of considerable thickness, and as there is a rich fauna of the *raricostati* collected in detail through many feet of strata, ranging from the elaborate anagenetic to extreme catagenetic forms, there will be an excellent opportunity to note the sequence of such forms even within the limits of the zone itself.

The Raasay Iron Ore is of Upper Lias date, but its exact zonal position will require very careful consideration of the evidence. It is by no means as simple a problem as might be supposed. Above the Raasay Iron Ore there would seem to be a very considerable gap in the sequence. The evidence has not yet been worked out in detail, but there seems to be reason to suppose that much of the Whitbian and all the Yeovilian is wanting. This opinion, however, may be modified when the work is completed.

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A careful examination of the Inferior Oolite strata led Dr. G. W. Lee to believe that the basement beds coloured on the one-inch map as Midford Sands should more properly be referred to zones in the Inferior Oolite proper. This opinion is now supported by Mr. Buckman, who re-examined the old materials on which this attribution had been based. Dr. Lee also found a richly fossiliferous ammonite-bed, approximately of Murchisonae date, which will probably permit of interesting comparisons between Raasay and Mull.

The base of the Estuarine Series contains an oil-shale which is referred to on page 40. Mr. S. S. Buckman finds that above the Estuarine Series there is evidence of marine Cornbrash. It may be stated that the Cornbrash was previously not known to be represented in the Jurassic rocks of the Hebrides.

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VI.—PHOTOGRAPHIC WORK.

(1.)—England and Wales.

In addition to the photomicrographic and miscellaneous work of the Department, photographs of geological subjects have been taken and added to the collection from the London District, South Wales and from the Midland Counties.

A series of geological photographs has been presented by Mr. H. C. McNeill. Dr. Teall and Dr. Strahan have presented valuable additions to the collection of photomicrographs.

(2.)—Scotland.

Photographs illustrating the geology of Argyllshire, Eastern Ross and Midlothian were taken during 1913. Twenty-six negatives illustrating Scottish geology have been presented by Mr. H. C. McNeill.

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VII.—MUSEUM OF PRACTICAL GEOLOGY.

An important addition to the series of geological models has been made by the acquisition of a model of the Thames Valley near Goring and Reading.

Temporary exhibits have been arranged to illustrate (1) the Memoir on the Geology of the Lizard District; and (2) the types of flint implements found in excavating gravels at Swanscombe, Kent, in co-operation with the British Museum.

By the courtesy of the Dean and Chapter of St. Paul's Cathedral an excellent illustration of the weathering of Portland Stone, in the form of a portion of an original statue, removed from the south transept during repairs, has been obtained on loan.

List of Donations during the year 1913.

Anderson, J. H., Esq., M.Inst.M.E.—A series of Micrasters and Brachiopods from the Chalk of Purfleet.

Baker, George, Esq.—A sample of Haematite from Shetland.

Bartlett, Dr. B. Pope, M.R.C.S.—*Catopygus columbarius* Lam. from the glauconitic sandstone of Carne Common, Shaftesbury, and a *Rostellaria?* from the Chloritic Marl of Maiden Bradley.

Barrow, G., Esq., F.G.S.—Two specimens of Staddon Grit from Bodmin, Cornwall; four specimens of Calc-flintas from Camelford and Tremore, Cornwall.

Bassold, Miss.—Samples of sand from India.

Berry, Dr. James, F.R.C.S., F.G.S., &c.—Specimens of volcanic mud from Pompeii.

Bevan, J. A., Esq.—Clay Iron-ore containing Blende from Poland.

Blechynden, A. C., Esq.—A series of specimens of Muscovite from India.

Boyd, Rev. F. C., B.A.—A stalactitic chalcedony from the Central Provinces, India.

Boynton, T., Esq.—Portion of a tusk of *Elephas primigenius* Blum. from the Boulder Clay of Skipsea, Yorkshire.

Brett, Cyril, Esq.—Zirlite in sandstone.

Brighton Public Library, Museums, and Fine Art Galleries.—A series of cores from the Sub-Wealden boring near Battle, Sussex.

Brizard, M. Rene.—A series of Flint Implements from La Claisière, France.

Burr, Dr. Malcolm, D.Sc., F.L.S.—Samples of coal from the Kent Coalfields.

Coglan, J. C., Esq.—Two specimens of Common Opal.

Collins, J. H., Esq.—A specimen of Tilberthwaite Slate, Westmorland.

Colonies, H.M. Secretary of State for the.—A specimen of Nigerian Tin-bearing Pegmatite.

Coward, W. M., Esq.—Specimens of Marbles from New South Wales.

Dalton, Miss E.—Specimens of gold-ore and galena from British Columbia.

Davenport-Handley, I. W. H., Esq.—Three samples of Clipsham building-stones.

Davies, Dr. A. M.—Rhaxella chert with an impression of *Cardioceras vertebrale* (J. Sow.) from Arngrove, Buckinghamshire.

Dickinson, H. W., Esq., A.M.I.Mech.E., &c.—A specimen of tin from the South Crofty Mine, Cornwall.

Dougal, Mrs.—Two specimens from the islands of S. Harris and N. Uist, Scotland.

Ebbs, Alfred B., Esq.—Specimens of Flint.

Ennor, John, Esq.—Samples of Cornish Clays.

Gamble, W., Esq.—A series of Bryozoa from the Chalk, and sponges in flint from the Micraster cortestudinarium zone of Luton, Chatham.

Grafton, T. E., Esq.—Two samples of American Halloysite.

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GREGORY, PROF. J. W., F.R.S.—One specimen 'Erratic' Essex.

HARTFREE, G. BERTRAM, ESQ., F.J.S.—A specimen of flint with twin percussion-cones. *Nautilus elegans* J. Sow. from the Lower Chalk of Alton, Hampshire.

HASLUCK, F. W., ESQ.—A flint and steel (modern), from Nigdeh in Cappadocia. A nodule of meerschaum and native cigarette-holders from Eski-Shehr, Asia Minor.

HAY, A. M., ESQ.—Tin and Copper-ore specimens from Katanga, The Congo.

HIKI, PROF.—Specimens of Chalcedony, Topaz and Arsenic from Japan.

HILL, CHARLES F., ESQ.—Specimens of Magnesite, &c., from Australia.

HIRANO, PROF. K., Tokyo.—A series of raw materials used in the Japanese production of porcelain.

HOLLOWAY, WILFRED, S., ESQ.—Specimens of Tremolite and Actinolite from Korea.

HOLMAN, C. V., ESQ.—Molybdenite in granite from Maine, U.S.A.

JACKSON, B., ESQ.—A set of trinkets made (by the donor) from stones found in Cyprus.

JOHNSTON, MISS M.—Samples of Egyptian Sandstones and Limestones. Samples of limestone-sand, also granitic sand from Egypt.

JUKES-BROWNE, A. J., ESQ., F.R.S.—A specimen of fused basalt.

KENDALL, REV. H. G., M.A.—Glaciated boulder of argillaceous limestone from the Lea Valley, near Hertford. A specimen of silicified wood from Hackpen Hill, Wiltshire.

KIERS, JOHN, ESQ.—A 'dogger' from the Oolite, found at No. 3 Shaft, Dover.

KINGSLAND, J., ESQ.—A series of Scheelite specimens from New Zealand.

LAMPLUGH, G. W., ESQ., F.R.S.—A series of specimens from Neocomian rocks of the Jura.

LANT, THOMAS, ESQ.—A specimen of bituminous mineral in diabase vein.

LORENZ, EDWARD, ESQ.—A Brandon 'Time candle' with flints attached.

MATLEY, DR. C. A.—A series of Bunter pebbles from the Drift of Warwickshire, and fossils from North Anglesey described in *Quart. Journ. Geol. Soc.*, vol. lv, pp. 635-680, and vol. lvi, pp. 233-256.

MCLEOD, PROF.—A specimen of banded felsite, from Snowdon, N. Wales.

MILLS, T., ESQ.—A series of specimens from a boring at Lowestoft.

MORROW-CAMPBELL, G. J., ESQ.—Eight specimens of Laterite from Ashanti.

NEWBERRY, C. HAROLD, ESQ.—A Fulgurite from Kalahari, South Africa.

OLDS, H. FRANCIS, ESQ.—A specimen of tin-ore from the Wheal Hermon Mine, Cornwall.

OWEN-ROBERTS, W., ESQ.—A specimen of Hone-stone from the Melynllyn Quarry, Carnarvonshire.

PADDINGTON, THE BOROUGH COUNCIL OF.—An old stone water-pipe.

PAGET, SIR R.—A rectangular dish in fused silica.

PARSONS, DR. H. FRANKLIN, EXECUTORS OF.—*Actinocrinus triacontadactylus* Mill. from the Carboniferous Limestone of Frome, Somerset, and bones of *Teleosaurus cadomensis* (Lam.) from the Fuller's Earth Rock of Hardington, Somerset.

PICKEN, R. W., ESQ.—Two specimens of copper-rocks from Bahia State, Brazil.

POLLARD, DR. W., M.A.—A specimen of Lundy Island granite.

PORTLAND CEMENT MANUFACTURERS, LTD., THE ASSOCIATED.—A tooth of *Elephas* from the Pleistocene of Barnfield Pit, Swanscombe, Kent.

PREUMONT, G. F. J., M.INST.M.M., F.G.S.—A series of specimens of South American (Bolivian) ores.

RATCLIFF, W. P., ESQ.—A cut synthetic ruby.

RHODES, J., ESQ.—Two specimens of Carboniferous Chert, from Swaledale, Yorkshire. One specimen of Sarsenstone from Gueutteville, Normandy.

RICHARDSON, LINSDALL, ESQ., F.R.S.E., F.L.S., F.G.S.—One hundred and eighteen Rhætic and contiguous rocks illustrating his papers. From Glamorganshire, Monmouthshire, Gloucestershire, and Somerset.

RIDLEY, T. W., ESQ.—A small sample of paving-block from 'George Washington's House' at Mount Vernon, Virginia, U.S.A.

ROBERTS, R. MEYRICK, ESQ.—A series of samples of blue roofing-slates from Corwen, North Wales,

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ROPP TIN, LTD., THE SECRETARY OF.—A very fine specimen of Cassiterite from Northern Nigeria.

ROSEN, LOUIS, ESQ.—A piece of Turquoise matrix.

SESSIONS, WALTER, ESQ.—A series of samples from the Stannon Moor China Clay Works, Cornwall.

SHERBORN, C. D., ESQ., F.Z.S.—*Inoceramus lobatus* Goldf. from the Quadratus Zone of Sewerby Flats, Yorkshire.

SIPUTEH TIN MINES, THE SECRETARY OF.—A Cassiterite vein in limestone-boulder, also many mineral specimens from the Malay States.

SMITH, STANLEY, ESQ., B.A., B.Sc.—Aulophyllum sp. from the Carboniferous Limestone of Bathgate, Linlithgow.

STRACHAN, C. E., ESQ.—A fragment of Millstone made in Niedermendig lava.

STRAHAN, DR. A., F.R.S., &c.—Specimens of Gypsum and Albertite from New Brunswick.

ST. PAUL'S CATHEDRAL, THE DEAN AND CHAPTER OF.—A fragment of a statue removed from the Southern Transept (on loan).

THOMAS, CAPTAIN J.—Specimens of wolfram and cassiterite from Cornwall.

THORNEYCROFT, WALLACE, ESQ.—Four specimens of Ironstone from Raasay Island, Inverness-shire.

TRECHMANN, C. T., ESQ., B.Sc.—A series of specimens illustrating a paper on 'Anhydrite in the Magnesian Limestone.'

TYRELL, PROF. J. B., M.A., B.Sc.—A micro-slide, Variolite, Strome Point, Upper Loch Fyne, Argyllshire.

WADE, DR. ARTHUR.—Specimen of Salt from Sodom. Specimen of bituminous conglomerate and bituminous calcareous shales, from the Dead Sea. Specimen of wind-etched gypsum from near Ras el Mesalla, Mount Sinai.

WATNEY, VERNON, ESQ.—Specimen of Zoisite Biotite Granulite, Ross-shire.

WATT, W. R., ESQ.—Fourteen specimens of Metamorphic Rocks from Aberdeenshire.

WHITE, MRS.—A specimen of Copper-ore from Jamaica.

WILKINSON, W. FISCHER, ESQ.—A sample of Cassiterite sand from Nigeria.

WILLIAMS, E. W., ESQ.—A topaz-crystal from Nigeria.

WRIGHT, W., ESQ., F.G.S.—A series of fossils, zonally collected, from the Chalk of Surrey.

YOUNG, G. W., ESQ., F.G.S.—*Cliona cretacea* (Portl.) from the Gravel of Merrow Down, Guildford.

YOUNG, DR. E. H., M.D., &c.—One specimen of Meldon Aplite, Meldon Quarry, Devon.

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VIII.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

(A.) ENGLAND AND WALES.

I.—MAPS.

(*a.*) *Four Miles to One-inch Maps* (*New Series*).

Title Sheet.
Index of Colours.

(*b.*) *One-inch Maps* (*New Series*).

(Colour-printed, price 1*s.* 6*d.* each.)

A colour-printed Drift Edition of each of the following Sheets has been issued in place of the hand-coloured edition:—

Isle of Man, Special Sheet.
Sheet 339, Newton Abbot.
Sheet 349, Ivybridge.
Sheet 350, Torquay.

(*c.*) *Six-inch Reference Maps.*

Seventeen MS. coloured copies of six-inch quarter sheets have been made from the field-copies, and deposited in the Library for public reference.

These are as follows:—

Pembrokeshire, 26 S.E.; 28 S.W., S.E.; 32 N.E.; 33 N.W., N.E.; 34 N.W., N.E., S.E.; 35 N.W., N.E., S.W., S.E.; 36 N.W., S.W.; 41 N.W., N.E.

II.—MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1912. pp. 101, 1 plate, 4 illustrations. Price 1*s.*

Records of London Wells. By G. Barrow, F.G.S., and L. J. Wills, M.A., F.G.S. pp. 215, 3 plates, 4 illustrations. Price 4*s.* 6*d.*

The Concealed Coalfield of Yorkshire and Nottinghamshire. By Walcot Gibson, D.Sc. pp. 122, 3 plates, 5 illustrations. Price 1*s.* 6*d.*

The Geology of the Country near Fareham and Havant (Explanation of Sheet 316). By H. J. Osborne White, F.G.S. pp. 96, 17 illustrations. Price 1*s.* 9*d.*

The Geology of the Country around Newton Abbot (Explanation of Sheet 339). By W. A. E. Ussher, F.G.S., with contributions by Clement Reid, F.R.S., J. S. Flett, M.A., D.Sc., and D. A. MacAlister, A.R.S.M. pp. 148, 3 plates, 14 illustrations. Price 3*s.*

The Geology of the Country around Ivybridge and Modbury (Explanation of Sheet 349). By W. A. E. Ussher, F.G.S., with Chapter on Altered Rocks by G. Barrow, F.G.S. pp. 137, 6 plates, 24 illustrations. Price 3*s.*

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(B.) SCOTLAND.

I.—MAPS.

(*a.*) *One-inch Maps.*

(Colour-printed.)

Sheet 64, ,, 82, ,, 92 } (Solid and Drift Geology.) Price 2*s.* 6*d.* each.

A colour-printed edition (Solid and Drift Geology) of Sheet 70 has been issued in place of the hand-coloured edition. Price 2*s.* 6*d.*

(*b.*) *Six-inch Maps of Mining Districts.*

Lanark, 3 S.E.

(*c.*) *Six-inch Reference Maps.*

The following copies of six-inch Maps have been completed and deposited in the office for reference:—

Argyll, 125, 140, 150, 160, 161, 170, 171, 180, 191, 202.

Caithness, 5, 18, 19, 20, 21, 22.

Ross, 1, 3A, 6, 6A, 12, 12A, 19, 19A, 20, 21, 22, 31, 32, 34, 35, 44, 48, 52, 72, 80, 80A, 82, 83, 93, 94, 102, 104, 105, 109, 109A (with 115), 110, 116, 117.

Sutherland, 7, 15, 19, 22, 23, 24, 30, 31, 40, 50, 59, 92.

Sheets formerly clean-copied but not reported as deposited which have now been checked, revised and deposited:—

Argyll, 246, 247, 251, 252, 256, 257, 258, 261, 262, 263, 264, 265, 266.

Ross, 28, 29, 30, 41, 42, 43, 54, 55, 65, 66, 67 (with 79), 76.

Skye, 13, 19.

II.—MEMOIRS.

Summary of Progress. See p. 93.

The Geology of Upper Strathspey, Gaick and the Forest of Atholl. (Explanation of Sheet 64.) By George Barrow, F.G.S., Lionel W. Hinxman, B.A., F.R.S.E., and E. H. Cunningham Craig, B.A.; with contributions by H. Kynaston, B.A. pp. 116, 4 plates; 2 text figures. Price 2*s.*

The Geology of Central Ross-shire. (Explanation of Sheet 82.) By B. N. Peach, LL.D., F.R.S.; J. Horne, LL.D., F.R.S.; L. W. Hinxman, B.A., F.R.S.E.; C. B. Crampton, M.B., C.M.; E. M. Anderson, M.A., B.Sc.; R. G. Carruthers, F.G.S.; with Petrological Notes by J. S. Flett, D.Sc., LL.D. pp. 114, 8 plates; 10 text figures. Price 2*s.* 3*d.*

The Geology of the Fannich Mountains and the Country around Upper Loch Maree and Strath Broom. (Explanation of Sheet 92.) By B. N. Peach, LL.D., F.R.S.; J. Horne, LL.D., F.R.S.; the late W. Gunn, C. T. Clough, M.A., F.G.S.; and E. Greenly, F.G.S.; with Contributions by L. W. Hinxman, B.A., F.R.S.E.; T. I. Pocock, M.A.; and C. B. Crampton, M.B., C.M.; and Petrological Notes by J. J. H. Teall, D.Sc., LL.D., F.R.S. pp. 127, 6 plates; 8 text figures. Price 2*s.* 6*d.*

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APPENDIX I.

The Heswall Boring.

By A. Strahan, Sc.D., LL.D., F.R.S.

This boring was made in the year 1908 on the shore of the Dee Estuary west of Heswall. The site, which is about 20 ft. above O.D., is 40 yds. inland from the edge of the cliff, and 180 yds. north of Bank Road. We were indebted to Mr. F. W. North, F.G.S., for an opportunity of examining the cores while the boring was in progress, and for permission to publish this account of them.

The boring commenced below the Glacial Deposits in the Upper Mottled Sandstone.[1] The site is 1,100 yds. west of the base of the Lower Keuper Sandstone, and about 290 ft. below it. Allowance being made for an assumed average dip of 2°, it may be estimated that the section commences about 400 ft. below the top of the Upper Mottled Sandstone. Except in the upper part the hole was kept at a uniform diameter of 3 ins. to the lowest depth reached.

Section of the Heswall Boring.

(Abstract of a section drawn up by Mr. Schill and communicated by Mr. F. W. North.)

		Thickness. Ft.	in.	Depth from surface. Ft.	in.
[Glacial] ...	Clay, pebbles and gravel	60	0	60	0
Upper Mottled Sandstone]	Soft red and white sandstone ...	108	0	168	0
[Pebble Beds] ...	Red quartzitic sandstone, micaceous in parts, with pebble-beds from 903 to 1,064 ft., and from 1,098 to 1,102 ft.	934	0	1,102	0
[Lower Mottled Sandstone]	Mottled and red-spotted sandstone, yellow and white in parts; quartzitic sandstone from 1,311 to 1,337 ft.	1,272	0	2,374	0
	Brown-black shale	7	0	2,381	0
	Brown-black shale, micaceous ...	4	0	2,385	0
	Sandy-black shale	5	0	2,390	0
	Purple shale	15	0	2,405	0
	Purple shale, calcareous	18	0	2,423	0
	Grey and purple shale	86	0	2,509	0
	Marly sandstone	5	0	2,514	0
	Purple shale with sandstone-bands	18	0	2,532	0
	Ironstone	1	6	2,532	6
	Marly sandstone	1	10	2,534	4
	Ironstone	0	8	2,535	0

[1] An account of this boring was published by Mr. A. Wade in the *Trans. Inst. Min. Eng.*, vol. xxxix, 1910. In this Mr. Wade gives a classification of the strata, which differs in some important particulars from that set out below. He believed the highest rock proved below the Glacial Drift to have been Lower Keuper Sandstone, and certain purple beds to have been Upper Coal Measures.

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	Thickness. Ft	in	Depth form surface. Ft.	in.
Purple, grey (calcareous) and green shale	43	3	2,578	0
Purple and black or brown shale	31	3	2,609	0
Dark-brown shales with some sandstone	39	11	2,649	5
Greyish-black sulphurous shale ...	3	7	2,653	0
Black shaly sandstone	0	9	2,653	9
Coal	0	9	2,654	6
Grey and black shale	28	8	2,683	4
Coal	0	3	2,683	7
Grey sandstone	11	7	2,695	2
Grey and black shale	14	4	2,709	6
Dark-grey sandstone	4	10	2,713	4
Black and grey shale	61	8	2,775	0
Dark-grey sandstone	11	0	2,786	0
Black shale...	1	0	2,787	0
Coal	1	0	2,788	0
Grey shale	2	3	2,790	3
Coal	1	3	2,791	6
Grey and black shale	63	6	2,855	0
Calcareous micaceous shale ...	25	0	2,880	0
Grey micaceous sandstone ...	6	7	2,886	7
Grey shale	33	5	2,920	0
Grey micaceous sandstone ...	83	0	3,003	0
Grey shale	4	0	3.007	0
Grey rosa, ? rosy sandstone ...	13	0	3,020	0
Grey and black shale	99	0	3,119	0
Grey oily shale	113	0	3,232	0
Coal	1	0	3,233	0
Grey shale	1	8	3,277	8
Grey shaly sandstone	11	0	3,288	8
Micaceous sandstone	33	4	3,322	0
Fireclay	4	0	3,326	0
Grey micaceous sandstone ...	13	0	3,339	0
Grey sandy shale	7	0	3,346	0
Hard grey sandstone	16	0	3,362	0

Carbonicola aquilina (J. de C. Sow.) was obtained by the late J. Lomas in the purple strata above the depth of 2,585 ft. From the shales between the depths of 2,837 and 2,863 ft. and of 3,220 and 3,264 ft., Mr. Pringle identified *Posidoniella laevis* (Brown), *P. sp.*, *Pterinopecten papyraceus* (J. Sow.), *Gastrioceras carbonarium?* (von Buch), *G. sp.*, *Glyphioceras reticulatum* (Phill.), and involute forms of Goniatites. Between the depths of 3,000 and 3,172 ft. also he identified *Glyphioceras reticulatum* (Phill.), *G. sp.* and involute forms of Goniatites. *Neuropteris schlehani* Stur was found at a depth of 3,270 ft. This plant was identified by Dr. Kidston, and is stated by him to be characteristically a Middle Coal Measure form, and never to have been seen by him below those measures.

The Trias calls for little remark. The Upper Mottled Sandstone presented its usual characters, and the base of it was drawn as nearly as might be where a more quartzitic character set in. The base of the Pebble Beds also was a matter of doubt. A red quartzitic sandstone 26 ft. thick occurred at a depth of 1,310 to 1,337 ft. To include this in the Pebble Beds would have involved including also 209 ft. of mottled and spotted-red sandstone which seemed to have more the character of Lower Mottled Sandstone.

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The total thickness of the Bunter in the neighbourhood appears to be:—

	Ft.	Ft.
Upper Mottled Sandstone, upper part estimated ...	400	
Upper Mottled Sandstone, lower part proved ...	108	
		508
Pebble Beds		934
Lower Mottled Sandstone		1,272
		2,714

The colour and marly character of the strata between the depths of 2,374 and 2,609 ft. were suggestive of Upper Coal Measures, but it is to be noticed that there were no limestones in them, though thin bands of that rock were proved to be of frequent occurrence in the Upper Coal Measures which underlie part of the estuary of the Dee.[1] The only fossil found moreover, *Carbonicola aquilina*, is a Middle Coal Measure form, which is not known to range up into the Upper Coal Measures.

From a depth of 2,857 ft. downwards the fossil evidence apart from the plant mentioned above indicated that the strata were older than the productive Measures of Flintshire and Parkgate. The fossils occurred in great abundance, and the assemblage resembled that which is found in the Holywell Shales of Flintshire and which is not known, and is certainly very rare, in or above the productive Measures of the Flintshire Coalfield. Some of the fossiliferous bands in the black shales were highly calcareous and closely resembled the limestones which have been worked for cement-making in the Holywell Shales near Holywell.[2]

The sandstones near the bottom of the boring had much the aspect of Millstone Grit. Some of them might be described as coarse quartz-grit and a few contained quartz-pebbles.

The boring therefore has proved a disappointment in the sense that it indicates that this part of Cheshire cannot be included in the area of possible coal-reserve. The explanation of the absence of productive Measures must remain at present a matter for surmise. There is a possibility, but no clear evidence, that the boring traversed a fault large enough to cut out all the workable coals. High dips were noticeable in some of the cores, especially at a depth of 2,674 ft. as observed by Mr. Wade. The fossiliferous shales and the grits in the lower part of the boring were gently inclined. It is equally possible, however, that the boring happened to be situated on a Carboniferous anticline, by which measures below the productive series were brought into unconformable contact with the base of the New Red Sandstone. A third hypothesis remains, namely, that the purple beds rest unconformably upon the supposed Holywell Shales, having overstepped the productive series. There is some evidence suggesting an overstep of part of the productive series by red unproductive strata near Flint, as described on p. 16.

[1] Sealands Boring No. 3 in the 'Supplement to the Geology of Flint, Mold and Ruthin' (*Mem. Geol. Survey*), 1898, p. 5.

[2] 'Geology of Flint, Mold and Ruthin' (*Mem. Geol. Survey*), 1890, p. 65.

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APPENDIX II.

On a Boring for Coal at Hemington, Somerset.

By T. C. Cantrill and J. Pringle.

Early in 1909 a boring for coal was commenced on a site close to the village of Hemington, 2½ miles east-south-east of Radstock; but having failed to prove workable seams, it was abandoned in the year following. Through the kindness of Mr. J. D. Armstrong, of Vallis Vale, Frome, permission was given to the Geological Survey to visit the borehole and examine the cores. As the thin cover of Jurassic and Triassic rocks which everywhere more or less conceals the Radstock coal-measures had to be passed through, the boring-operations promised to be of more than usual interest. Unfortunately, however, much of this was lost through the cores of the Jurassic and Triassic rocks having suffered severely from the weather before our visits in March and July, 1910. The Coal Measure cores, especially the earlier ones, were perhaps in an even worse condition. These, owing to lack of shed-room, had been piled one upon another, so that their examination was a matter of considerable difficulty. This was particularly unfortunate; for, had they been laid out in single rows, we have reason to believe that the overfolding and overthrusting, known to affect the local Coal Measures and signs of which were seen in the cores, could have been worked out more or less completely.

The Geological Survey map (Old Series, Sheet 19), shows that the surface-formation is the Upper Fuller's Earth, with the Fuller's Earth Rock cropping out in lower ground a little farther east. With this mapping the results of the boring are in agreement. The map shows also, next below the Mesozoic rocks, the outcrop of the Pennant Grit; but on neither lithological nor palæontological grounds can any of the rocks in the boring be referred to that part of the Coal Measures.

The following is the section of the borehole:—

Boring for Coal, 300 yards west of Hemington Church, near Radstock, Somerset, 1909–10. Geological Map, Old Series, Sheet 19; 1-inch New Series Ordnance Map, Sheet 281; 6-inch, Somerset 29 N.E.—Height of surface above O.D. about 450 ft.

About 265 yards west of Hemington Church the road to Ammerdown makes a southerly bend, at which point a hedge leaves the road and runs westward. The boring was put down close to, and on the south side of, this hedge, at about 35 yards distance from the bend.

		Thickness. Ft.	in.	Depth. Ft.	in.
	Surface soil and clay	6	0	6	0
Fuller's Earth ...	Clay, dark greenish grey, with small *Rhynchonellae*	26	0	32	0
	Limestones, dark grey, earthy, with thick marly partings (Fuller's Earth Rock)	15	0	47	0
	Clay, dark greenish-grey, with *Ostrea acuminata*. J. Sow. ...	1	6	48	6
	Clay, dark grey, with lighter-coloured bands	38	6	87	0

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			Thickness. Ft.	in.	Depth. Ft.	in.
Inferior Oolite	Anabacia Rubbly Beds	Limestone, brownish, thin and irregular, full of crushed Terebratulas	0	1	87	1
	Anabacia Limestones	Limestone, compact, creamy, full of worm-borings and casts of large Oysters	1	0	88	1
		Oolite, creamy-white, with abundant *Anabacia complanata* Defr.	5	6	93	7
	Doulting Stone	Limestone, compact, creamy ...	0	10	94	5
		Oolite, creamy-white, with *Anabacia*	13	6	107	11
		Limestone, compact, creamy ...	1	6	109	5
		Oolite, creamy-white	3	6	112	11
		Limestone, compact, creamy ...	1	6	114	5
		Oolite, creamy-white	4	6	118	11
		Limestone, dark, earthy, irregularly oolitic and ironshot. Fossils occur in non-oolitic portions, and appear to have been derived from underlying bed. From 6 to 9 in., average	0	7	119	6
	Upper Trigonia Grit	Limestone, grey, earthy, irregularly-bedded, with many fossils (*Trigonia*, etc.), passing down into grey compact limestone with *Acanthothyris spinosa* (Schloth.)	6	6	126	0
Lias		Clay, dark bluish	25	0	151	0
		Limestone, dark grey, ironshot, with *Terebratula radstockensis* Dav. and Ammonites	4	0	155	0
Rhætic		Limestones, compact, whitish, becoming thinner-bedded and marly below (White Lias) ...	19	0	174	0
		Shales, dark, papery (*Pteria contorta* Beds)	23	0	197	0
Keuper Marl ...		Red marls, bright, becoming more sandy towards base	139	0	336	0
Coal Measures ...		Purplish-red marl at or near the top, underlain by grey shales with abundant ironstone-nodules; thick, gritty sandstones, fireclays, and thin coals (varying from ¾ in. to 1 ft.)	864	0	1,200	0

From the Fuller's Earth few fossils were obtainable, owing to the condition of the cores. Although the junction of the Inferior Oolite with the Lias was not seen, it is certain that there were no Inferior Oolite deposits of pre-*garantiana* date. In the Inferior Oolite, each of the sub-divisions recently established by Mr. L. Richardson,[1] excepting the Upper Coral-bed and the Dundry Freestone, was recognised. Apparently, therefore, there is a non-sequence between the Doulting Stone and the Upper Trigonia Grit; and evidence of erosion was noticed at the base of the former.

The cores of Lias clay were too badly weathered to yield any reliable evidence of their zonal position. The underlying 4 ft. of dark-grey ironshot limestone proved, however, to be highly fossiliferous, and yielded the following ammonites, viz., *Platypleuroceras*

[1] 'The Inferior Oolite and Contiguous Deposits of the Bath-Doulting District.' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 383.

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aureum (Simp.), *Polymorphites polymorphus* (Quenst.), and cf. *Rhacoceras wechsleri* (Oppel), which were identified by Mr. S. S. Buckman, who referred the bed to the Valdani Zone. Between the 4 ft. limestone and the top of the White Lias there is a marked discordance. All the zones between the Valdani Zone and the Sun-bed are missing, and the non-sequence of the two formations was well-shown in the cores by the uneven nature of the junction.

In the Rhætic formation the uppermost beds of the White Lias proved to be a group of compact whitish limestones, 4 ft. thick, of which the Sun-bed formed the highest member. At about 3 ft. below the top, a specimen of Cotham Marble had been obtained by Mr. Armstrong. The lowest White Lias cores could not be examined, as they were concealed by the clays of the Lias. The *Pteria contorta* Beds were poorly represented in the cores, nearly all of them having broken down under the weather. They seem, however, to have been the ordinary dark paper-shales, but no bone-beds were noticed.

The Tea-green Marls were apparently absent. The rest of the Keuper Marls were bright-red marls, with five bands of hard sandy marl near their base; but no conglomerate was passed through in the boring. It appears that in the Radstock district "the occurrence of the Dolomitic Conglomerate beneath the Red Marl is not invariable; thus whilst there were 6 ft. of it in Simon Hill's pit, near Paulton, there was no trace of it in Paulton lower pit."[1]

The boring entered the Coal Measures at a depth of 336 ft., and operations were continued until a depth of 1,200 ft. was reached, when, as no workable beds of coal had been passed through, they were abandoned. The strata met with are summarized in the table on p. 99, and do not differ from the measures recorded in other parts of the Radstock coalfield. One bed passed through, however, deserves mention, as it determines the horizon of the strata first encountered. This is the thick red purplish marl or shale that was met with at or near the top of the measures, and is known to occur about midway between the Radstock and the Farrington coal-groups. Unfortunately, owing to the manner in which the cores had been laid out, it was impossible to ascertain its thickness; but elsewhere in the coalfield it had been found to be from 130 to 250 ft.[2] Where first entered in the boring, the red shales are said by Mr. Armstrong to have had a dip of 15°.

Between the depths of 800–1,000 ft. the beds exhibited various dips, and appear to have undergone considerable crushing. So far as the order of the cores was determinable, there is reason to suspect that the disturbance was accompanied by overfolding. A bed of dark carbonaceous shale containing fragments of plants and shells (*Anthracomya*) noted between 580-600 ft. was apparently passed through three times, for a similar bed, characterised by the same fossils and bearing the same relation to a group of gritty sandstones, was seen at 900 ft. and at 1,050 ft. At the first-mentioned depth, the bed occurred below the sandstones; at 900 ft.

[1] H. B. Woodward, 'Geology of East Somerset and the Bristol Coalfields' (*Mem. Geol. Surv.*), 1876, p. 61.

[2] J. McMurtrie, 'The Geological Features of the Somerset and Bristol Coalfield, with Special Reference to the Physical Geology of the Somerset Basin.' *Trans. Inst. Min. Eng.*, vol. xx, 1901, p. 306.

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it was above them; while at 1,050 ft. it was again below. The position of this shale-band, therefore, affords a clue to the movements that affected the measures. Such 'slide' faults are a common feature in this coalfield, and are numerous in the Radstock district. Mr. McMurtrie has already described several that affect the seams of that neighbourhood.

The failure to find the seams of the Farrington Series may be due to the overthrusting and overfolding which we had reason to suspect from our examination of the cores. The movement appears to have resulted in the duplication of the measures, so that the boring was abandoned at a horizon not far below that first encountered after the cover of Jurassic rocks was pierced. The plants collected from the cores corroborate this view. Dr. Kidston, to whom the fossils were submitted for examination (the horizon given him being '?Farrington series'), says in a letter "as far as the species indicate, the rocks from which they come might be equally referred to the Radstock. The whole of the plants contained in the collection are common to both the divisions of the Radstockian series, viz., Radstock and Farrington Groups. They are typically Upper Coal Measures." The following is a list of the fossils obtained from the cores between 336 and 1,200 ft.:—

Annularia sphenophylloides (*Zenker*)
Lepidodendron sp.
Lepidophloios?
Lepidophyllum sp.
Sigillaria sp.
Sphenophyllum emarginatum *Brongn.*
Alethopteris aquilina (*Schloth.*)
,, *cf.* grandini (*Brongn.*)
,, serli (*Brongn.*)
,, sp.
Dactylotheca plumosa (*Artis*), *var.* dentata *Brongn.*
Mariopteris muricata (*Schloth.*)
Neuropteris flexuosa *Sternb.*
,, macrophylla *Brongn.*
,, rarinervis *Bunbury*
,, scheuchzeri *Hoffm.*
,, sp.
Pecopteris cyathea (*Schloth.*)
,, miltoni (*Artis*)
,, unita *Brongn.*
,, sp.
Sphenopteris neuropteroides (*Boulay*)
Anthracomya *cf.* phillipsia (*Will.*)

We conclude therefore that the first Coal Measures entered by the boring are the Red Shales known to occupy an intermediate position between the Radstock and the Farrington seams, and that the lowest beds reached lie between the Red Shales and the Farrington coals; that this latter group of coals was not reached at the depth expected, because the overlying grey measures had been abnormally thickened by overfolding and overthrusting; and that the boring ended at a horizon far above the Pennant Grit, which must consequently crop out, under the Mesozoic rocks, well to the south-east of the position assigned to it upon the map.

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APPENDIX III.

Additional Notes on the Geology of the Lothian Shale-field.

By R. G. Carruthers.

In the 2nd edition of the Memoir on 'The Oil-Shale Fields of the Lothians,' when remarking (p. 19) on the Fraser Shale of Cobbinshaw, the following statement is made, "it appears very probable that it (*i.e.*, the Fraser Shale) is identical with the Raeburn Shale of the West Calder Field."

This conclusion was based on the relatively imperfect sections of the Raeburn strata provided by chisel bores put down many years ago. A diamond bore recently executed for Young's Oil Company, in the West Calder region, has shown quite clearly that the Fraser Shale is a distinct seam, lying some 25 fms. above the Raeburn Shale. The conclusion also follows that the so-called 'Mungle' Shell-bed should rather be termed the Raeburn Shell-bed, and as a matter of fact it was found in the boring immediately under a shale known definitely to be the Raeburn, from the original workings in that seam visible in the immediate neighbourhood.

For permission to examine this important boring, which has for the first time given us a clear section from the Hurlet Coal down to the Raeburn Shale, we are indebted to the courtesy of Mr. John Fyfe, who has also consented to the publication of the foregoing statement.

Another new point concerning the geology of the shale-fields may also be mentioned. At the Rosyth Naval Base, the recognition of the Burdiehouse Limestone (Oil Shale Memoir, p. 83) has been confirmed by a dock excavation in which the Limestone itself is exposed along with a representative of the overlying Camps Shale, here badly 'burnt' by the great quartz-dolerite sill of Rosyth Castle. It is of interest to note that resting on the shale is a marine band a few inches thick, containing *Goniatites* and lamellibranchs (*Actinopteria fluctuosa*) in indifferent preservation.

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284. BASINGSTOKE	—	1 6	2 0
295. TAUNTON and BRIDGWATER	—	1 6	2 0
298. SALISBURY	—	1 6	1 3
299. WINCHESTER	—	1 6	1 6
300. ALRESFORD	—	—	1 6
311. WELLINGTON and CHARD	—	—	1 6
314. RINGWOOD	—	—	1 6
315. SOUTHAMPTON	—	1 6	
316. HAVANT	—	1 6	
317. CHICHESTER	—	1 6	
325. EXETER	—	1 6	
326 and 340. SIDMOUTH and LYME REGIS ...	—	1 6	
328. DORCHESTER	—	1 6	
329. BOURNEMOUTH	5 3	1 6	
330. NEW FOREST (pts.), I. of WIGHT (pts) ...	7 6	1 6	
331. PORTSMOUTH and I. OF WIGHT (pt.)	5 3	1 6	
332. BOGNOR	2 0	1 6	
333. WORTHING and ROTTINGDEAN	—	1 6	
334. NEWHAVEN and EASTBOURNE	—	1 6	
335. TREVOSE HEAD	—	1 6	
336. CAMELFORD	—	1 6	
337. TAVISTOCK and LAUNCESTON	—	1 6	
338. DARTMOOR	—	1 6	
339. NEWTON ABBOT	—	1 6	
341. WEST FLEET	—	1 6	
342. PORTLAND and WEYMOUTH	—	1 6	
345. SWANAGE	—	1 6	
346. NEWQUAY	—	1 6	
347. BODMIN and ST. AUSTELL	—	1 6	
348. PLYMOUTH and LISKEARD	—	1 6	
349. IVYBRIDGE	—	1 6	
350. TORQUAY	—	1 6	
351 and 358. LAND'S END DISTRICT	—	2 6	
352. FALMOUTH and TRURO	—	1 6	
353. MEVAGISSEY	—	1 6	
355. KINGSBRIDGE	—	1 6	
356. START POINT	—	1 6	
357 and 360. ISLES OF SCILLY	—	1 6	
359. LIZARD	—	1 6	
LONDON (4 Sheets), each ...	—	1 6	
ISLE OF MAN (Sheets 36, 45, 46, 56 and 57)	11 0	2 6	
ISLE OF WIGHT (Special Sheet)	—	2 6	
NOTTINGHAM (Special Sheet)	—	1 6	
OXFORD (Special Sheet) ...	—	1 6	

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1914.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1914.

I.—*INTRODUCTION.*

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

The field-work during the year 1914 was carried on in England and Wales in the three districts of (1) Denbighshire, with parts of the adjacent counties, (2) Warwickshire and Staffordshire, (3) London and the South-East.

In the Denbighshire District work was carried southwards in Shropshire as far as Shrewsbury, and in the Lower Palæozoic rocks west of the Carboniferous tract. The small part of Lancashire, including Liverpool, which falls within the one-inch Sheet 96 was surveyed.

In Warwickshire much attention has been devoted to the red unproductive measures which form the uppermost part of the Carboniferous group.

In the London and South-Eastern District the work has proceeded eastwards on both sides of the Thames. All three divisions of the Chalk and the Lower London Tertiaries have come under examination, as far upwards in the sequence as the Claygate Beds, an outlier of which has been detected near Willesden Green.

In all three districts the Superficial Deposits are of great importance in respect both of wideness of distribution and thickness.

In Scotland the mapping of the interior of the Island of Mull has been completed and that of the Highlands has been continued. The revision of the Coal Measures of the Lanarkshire Coalfield has been completed during the past year by the mapping of the Hamilton District.

The principal points of interest which result from the work upon the various geological formations may be summarised as follows:—

CRYSTALLINE GNEISSES AND METAMORPHIC SCHISTS.

Field-work has been continued in the interior of Sutherland where the rocks belong partly to Moine types, and partly to more crystalline facies of gneiss that have a resemblance to the

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Lewisian gneisses west of the Moine thrust, though they cannot be proved to be identical with them. The difference between these two types is marked, but their boundaries are uncertain, and it is not easy to obtain evidence regarding their relative ages. So numerous in places are veins and sills of granite that it is impossible to map the injections, and in such cases the maps indicate regions of synthetic gneiss or granitised gneiss.

About Dalwhinnie Newer Granite masses, intruded into Moine Schists, have locally dissolved included fragments of schist, and thus assumed a darker colour due to a greater abundance of black mica.

In Northern Inverness-shire an outcrop of quartzite, mica-schist and limestone surrounded on all sides by Moine rocks, may prove, when more fully mapped out, to be an extension of the well-known Laggan limestone. It is possibly an outcrop of the Lochaber Series, and may have some connection with the limestone and graphitic mica-schist of Grantown in the Spey Valley.

PRE-CAMBRIAN.

The surveying of the Longmyndian Rocks in Shropshire has been commenced. In Leicestershire the syenitic rocks which protrude through the Keuper Marls are undergoing examination.

ORDOVICIAN.

The greater part of the Ordovician ground surveyed during the year falls within the outcrop of rocks of Llandilo age. Mudstones, cleaved and sparsely fossiliferous, form the bulk of the sediments, but there is evidence also of not less than four volcanic episodes. Four groups known in descending order under the names of Mynydd-Tarw, Gwern-feifod, Garwallt and Craig-y-Glyn are recognised provisionally, but may be of only local significance. The palæontological evidence does not suffice to fix precisely the upper and lower limits of the Llandilo Beds.

SILURIAN.

The mapping of Wenlock Shale has been continued near Llanfyllin. Llandovery-Tarannon beds have not so far been recognised in this neighbourhood.

MIDDLE OLD RED SANDSTONE (SCOTLAND).

The Old Red Sandstone outliers north of Lairg consist of conglomerates and red or brown sandstones, and are probably to be assigned to the Middle Old Red Sandstone (Orcadian), of which a large outlier forms the well-known mountain called Ben Griam to the west of Forsinard.

UPPER OLD RED SANDSTONE (SCOTLAND).

A considerable thickness of the rocks of this group lies below the Carboniferous lavas of the West of Scotland in the district between Largs and West Kilbride, and the junction line between these two formations has been mapped for a considerable distance. In South Lanarkshire there is evidence of profound erosion of the Lower Old Red Sandstone before the Upper Old Red Sandstone was deposited.

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CARBONIFEROUS.

In the Carboniferous Limestone Series of Denbighshire evidence of an overlap of the lower by the upper beds in a southward direction has been obtained. The upper limit of the limestone-series is difficult to define, as was the case also farther north, owing to the intercalation among the limestones of sandstones which simulate Millstone Grit. In the Millstone Grit, which was described by Morton under the name of Cefn-y-fedw Sandstone, some sub-divisions of local significance can be recognised. The Chert Beds of Ruabon Mountain are represented.

Etruria Marls with Espley Rocks occur in typical aspect in Denbighshire and Shropshire under the name of Ruabon Marls, but the upper members of the unproductive red and grey Carboniferous rocks are overstepped by Trias or deeply buried under Drift in the area surveyed during the year, except for exposures of Keele Beds near Shrewsbury. In Warwickshire these unproductive measures have been ascertained to form a conformable series not less than 3,250 feet thick, and to pass down into the productive measures. The Etruria Marls lose their red tint in the southern part of the Warwickshire coalfield, but always include characteristic Espley Rocks. The uppermost Carboniferous beds are overstepped by the Trias in the part of Warwickshire surveyed, and in Staffordshire the position of the top of the group is only now coming up for consideration. Two notable borings which traverse a large part of the unproductive measures are illustrated on p. 21.

In Scotland the extensive area formed of rocks of the Carboniferous Limestone Series around Paisley and Johnstone has now been completely revised. South of Kilmarnock a nearly horizontal plane of dislocation traverses the strata, and at one place cuts out at least 50 or 60 feet of sandstones and shales. The revision of the Coal Measures of the Lanarkshire Coalfield has been completed as noted above.

IGNEOUS ROCKS IN THE SCOTTISH CARBONIFEROUS.

In the Dalry District volcanic necks have been filled with dark-green ash containing marine fossils of the Carboniferous Limestone, and thus affording evidence of the age of the volcanic outburst.

Some long narrow veins of volcanic ash have been observed in coal-pits near Kilmarnock. They are mostly vertical, but at times follow the bedding-planes. Their courses have not been determined by lines of fault, but may have been due to the rending apart of the strata by stresses set up during volcanic explosions.

TRIAS.

The mapping of the Trias in and near Liverpool has confirmed generally the work done by Morton.

In Shropshire the Bunter rapidly oversteps the underlying rocks from Keele Beds to the Carboniferous Limestone Series. It preserves its normal aspect, but the Lower Keuper Sandstone loses in a southward direction the characters which distinguish

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it from Upper Mottled Sandstone farther north. At Haughton a deep boring has revealed, under deep Drift, upwards of 300 feet of Keuper Marl, where Bunter was believed to occur.

In Leicestershire a "head," almost certainly of Triassic age, has been noticed in the Lane Hill Quarry, Stoney Stanton.

JURASSIC (SCOTLAND).

In Raasay an exceptionally fine series of fossils has been collected from the rocks associated with the ironstone and oil-shale. In Skye, the Lower Oolites attain a large development as compared with their meagre thickness in Mull, and contain many large and well-preserved ammonites.

The beds previously mapped as Rhætic in Applecross have been shown to belong to the base of the Lias.

CRETACEOUS.

In the London District the tracing of the horizon of *Heteroceras reussianum* has been continued and the Melbourn Rock has been mapped for some distance, the Lower Chalk now entering the area under examination. A fault, hitherto supposed to form the boundary of the Chalk on the south side of Plumstead and Erith Marshes, has been proved not to exist. The effects attributed to it are due to dip.

TERTIARY.

The Thanet Sand, expanding eastwards, attains a maximum thickness of about 60 feet in the area under examination. It rests on different horizons in the Upper Chalk, in a manner which suggests slight pre-Tertiary bending.

Further evidence has been met with of erosion having accompanied the formation of the Blackheath Pebble-beds; in extreme cases the hollows, into which the pebbles have been swept, cut completely through the Thanet Sand.

The outlier of Claygate Beds on Shooter's Hill, and a hitherto unknown outlier at Willesden have been examined.

In Scotland, with the completion of the survey of the interior of Mull, more definite conclusions regarding the history of the intricate volcanic structures become possible. The remains of a great 'caldera' have been recognised in the neighbourhood of Loch Bà and to the south of that loch. Its southern and eastern margin can be traced for a considerable distance, and the volcanic breccia, of which descriptions have been given in previous 'Summaries of Progress,' apparently represents the ejectamenta of vents situated on that margin. That the breccia is a volcanic agglomerate was believed originally by Professor Judd and Sir Archibald Geikie.

In the interior of the 'caldera' there are great lava-flows, aggregating 2,000–3,000 feet in thickness, which frequently exhibit 'pillow-structure' in great perfection. This structure is found only in lavas that have congealed under water and leads to the belief that the 'caldera' was at times occupied by a lake.

The special feature of the geology of the centre of Mull is the presence of numerous 'ring-structures' such as are known also in the cauldron-subsidences of Glencoe and Ben Nevis, and in a

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few other places. These are evidenced by the occurrence of inclined sheets of basic and acid rocks that have arisen through fissures dipping inwards towards the centre. Their outcrops describe curves, which are greater or less segments of circles. It must be noted, however, that the centre of the series of intrusions was not constant in its position, but shifted in course of time along a north-west line for a distance of two miles. Vertical intrusions of circular shape (ring-dykes of gabbro, &c.) are also found, especially in the district south of Loch Bà. The best example is the great Loch Bà felsite-intrusion, long known to geologists, which has now been traced along its whole course. It is believed to follow a circular fault along which the area on the inner side has undergone depression. The presence of other faults of this character has also been demonstrated, and it is thought that the Mull Caldera was bounded by a dislocation of this type giving rise to a cauldron-subsidence.

PLEISTOCENE.

On the borders of North Wales the existence of two drifts, the one of northern derivation and the other transported from the Welsh hills, is clear, but it has proved to be impossible to draw a precise line of boundary between them. There is obviously overlapping, due presumably to alternate retreat and advance of the respective ice-sheets. The direction of transport is S.S.E. in the case of the northern drift, and among the boulders are included shell-fragments; the direction is eastward in the case of the Welsh drift, and the boulders are assignable to Welsh sources. The thickness of the drift in Shropshire is notable. In Warwickshire also two drifts are recognised, the one covering the eastern part of the county and characterised by boulders brought from a north-eastern source, the other lying to the west of the coalfield and containing boulders brought from the north-west.

In the London District the investigation of the high-level gravels has proceeded. Among the few occurrences to the south of the Thames, one lies at a height of 600 feet above the sea. A Pliocene age for this occurrence has been suggested, but has received no confirmation. On the north of the Thames the gravel which so constantly occurs at an elevation of about 400 feet has been followed northwards and eastwards and found to pass under Chalky Boulder Clay. Where it descends to lower levels it begins to contain Bunter pebbles and other foreign material. Laminated clay occurs in the glacial deposits near Ware, an unusual circumstance in this part of England.

1.—Denbighshire and Shropshire District.

T. C. Cantrill, B.Sc., District Geologist

C. B. Wedd, B.A.
B. Smith, M.A.
W. B. R. King, B.A.
D. A. Wray, B.Sc.
} Geologists.

During the past season the examination of the Liverpool District, necessary to complete the re-survey of the New Series

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Sheet 96, has been commenced and nearly completed. In the Wrexham Sheet (121) further colliery information has been collected. In the Oswestry Sheet (137) the survey of the Denbighshire coalfield has been carried southward as far as Oswestry; the mapping of the older rocks on the west has advanced beyond the Tanat Valley towards Llanfyllin, and the newer formations on the east have been investigated as far south as the River Vyrnwy. Work has been commenced in the Shrewsbury Sheet (152) also, between the county town and Wellington.

Progress has been somewhat impeded by the withdrawal of Mr. King at the end of September for military service, and by other causes directly connected with the state of war.

PRE-CAMBRIAN.

The examination of the Longmyndian rocks of Haughmond Hill, near Shrewsbury, has been commenced by Mr. Cantrill. As is well known, this hill consists of an unfossiliferous series of purple conglomerates, greywackés, purple and grey-green sandstones and shales, with one or two bands of igneous rock. The rocks are not cleaved and maintain a uniform dip in an east-south-easterly direction, at angles decreasing from about 90° in the west to 50° in the east. The outcrop has been found to extend nearly half-a-mile farther east than is shown on the old map (61 N.W.), and a deep boring at Roden (p. 11) entered the Longmyndian rocks at the unexpectedly small depth of 25 feet.

ORDOVICIAN.

In the Oswestry Sheet Mr. King worked southward from the Ceiriog Valley to join up with the ground north of the Tanat Valley, surveyed by Mr. Smith in 1913 from Llanrhaiadr-ym-Mochnant.

In this great area of cleaved and practically barren mudstones and shales the chief bed of interest is the ash of Mynydd-Tarw, which has been traced to the western edge of the sheet at Blaen-y-cwm. This ash, which is alluded to in last year's Summary (p. 8), was noted by Lomas,[1] who, however, thought there were two separate bands; whereas it has been found that, in Cwm-Ty'n-y-fedwyn, the ash is folded, and its outcrop repeated by its intersection with the slope of the hill. It thins out toward the east, and is considered to be the probable equivalent of the ashy beds and grits detected by Mr. Smith on Mynydd-Mawr and Hên-fache.

Mr. King is of opinion that the Mynydd-Tarw Ash lies higher in the sequence than the volcanic rocks of Godor, which include a bed of ash, and a composite bed of lava overlain by ash—the latter falling outside the limits of the map. These form the northern continuation of the sequence established last year by Mr. Smith between Gardden-fawr and Gwern-feifod, on the northern side of the Rhaiadr Valley, the Godor vesicular lava being the equivalent of the Gwern-feifod vesicular lava, and the Godor ash of the Gardden-fawr ash.

[1] *Proc. Geol. Assoc.*, vol. xx (1907-8), p. 491.

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The Mynydd-Tarw beds, which are the downward continuation of the 'beds below the Cwm-Clwyd Ash' of the Ceiriog district, have been found to dip northward beneath the Cwm-Clwyd Ash, as described in previous Summaries; and it is now, therefore, possible to link up the sequence and to review the structure of the rocks below the Cwm-Clwyd Ash mapped in the heart of the Berwyn uplift. The Teirw Beds above that ash appear, on the evidence of the fossils, to be of Glenkiln age; but the question as to whether they should be assigned to the Llandilo or to the Bala must be left open for the present.

The following descending sequence, put forward provisionally, shows the connection between the rocks of the Glyn-Ceiriog district and those near Llanrhaiadr:—

General Sequence, Glyn-Ceiriog to Llanrhaiadr.

?Llandilo	... ...	*Cwm-Clwyd Ash.*
Llandilo	Mynydd-Tarw Group	Flaggy mudstones and shales.
		Fossiliferous grit.
		Shales.
		Mudstones and shales, with sandstones of Craig-yr-hweh, Foel-Rhiwlas and Foel-Wylfa.
		Mynydd-Tarw Ash and equivalent impure ashes and grits of Mynydd-Mawr and Hên-fache.
		Shale and mudstones with ashy and gritty sediment.
	Gwern-feifod Group	*Gardden-Fawr Ash* (25–30 ft.) = *Godor Ash.*
		Shales and mudstones and felspathic shales.
		Compact ash and ashy shales, overlying *Gwern-feifod Vesicular Lava* (20–30 ft.) = *Godor Lava.*
		Shales and mudstones.
		Platy ashes and shales.
		Shales and mudstones.
	Gap in sequence due to faulting.	
	Garwallt Group	Shales with occasional ashes and ashy shales.
		Garwallt Ash.
		Blue shales.
	Craig-y-Glyn Group	*Llandilo limestone* and calcareous flags.
		Fossiliferous ash, with basal conglomerate at Carnedd-y-forwyn.
?Llanvirn	... ...	Blue shales with sandy laminæ.

The argillaceous members of the above-named groups are all cleaved, as are the ashes also, in places. The ashes are generally siliceous, and of a pale tint; frequently they contain much sediment, and locally show brown spots of pumiceous material. Some of the more muddy ashes are highly felspathic.

In structure the rocks form the eastern part of an anticlinal dome, complicated by subsidiary folding. The axis of the uplift ranges generally east-and-west, with a slight pitch to the east; and the Mynydd-Tarw beds form a belt to the north, east and south-east of the Gwern-feifod volcanic group. Numerous east-and-west subsidiary folds increase the apparent thickness; and the large lateral shift of some of the outcrops, effected

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apparently by faulting alone, is due to the folded condition of the beds, rather than to the magnitude of the faulting.

Among the higher beds of the Mynydd-Tarw group in the Ceiriog Valley Mr. King finds that the dolerite of Mynydd-bâch (north-west of Llanarmon-Dyffryn-Ceiriog) occupies a lower horizon than that of the Hendre quarry, and that both were intruded subsequently to the cleavage of the shales. The Hendre rock appears to be a composite intrusion. The sandstones of Foel-Rhiwlas, Craig-yr-hwch, and Pen-y-gwely Reservoir, estimated at 300-400 ft. in thickness, pass in a westerly direction into sandy mudstones.

The Cwm-clwyd Ash, east of Llechrhydau, is a magnificent agglomerate, containing lumps of pink felsite.

In the Tanat Valley Mr. Smith continued his work in the neighbourhood of Llangedwyn and Llanyblodwel, the rocks surveyed being chiefly the easterly extensions of the Bala sandstones and shales mapped last year on the southern side of the valley. The sediments are all fossiliferous, being characterised by forms of *Trinucleus*, crinoids, and brachiopods, and are thrown into a series of folds. As before, the relations of dip to cleavage in this area prove beyond doubt that the cleavage antedates the folding.

In a dingle near Glan-yr-afon some dark graptolitic shales, overlain by greyer fossiliferous calcareous shales and mudstones, and thin impure limestones, may represent the horizon of the Pen-y-garnedd dolomitic limestone, described in last year's Summary (p. 9), in contact with which may be seen some black graptolitic shales originally discovered by John Morris and D. C. Davies. More material is necessary to determine the exact horizon of these shales, but it is not unlikely that this graptolitic facies may represent some part of the black Dicranograptus Shales of South Wales. They are probably equivalent to the Blaen-y-cwm beds of the Ceiriog district.[1]

In the area mapped by Mr. King, south of the Tanat Valley, between Llanrhaiadr and Llanfyllin, it has been found that the reversed Lower Bala beds are followed by about 1,200 ft. of strata referable to the Ashgillian stage. Of these beds the basal member is a phosphatic deposit, which has been mined at several places.[2] Above the phosphate-bed follow green-grey shales with trilobites of Ashgillian affinities. The phosphate-bed itself may mark a temporary break in deposition, and may form a good base to the Ashgillian, as new fossils (cystids, etc.) come in just above it. Such a break would account for the local or complete disappearance of the Bala limestone of Pen-y-garnedd when followed eastward; while farther west, phosphatic deposits have been recorded[3] as associated with the south-eastern margin of the Bala limestone.

Beds of the same character, and probably of the same Ashgillian age, were found by Mr. Smith in the district south of Llanyblodwel, the fossils including polyzoa, small brachiopods,

[1] 'Summary of Progress' for 1912 (*Mem. Geol. Surv.*), p. 8.

[2] D. C. Davies, *Quart. Journ. Geol. Soc.*, vol. xxxi, 1875, p. 357. *Geol. Mag.*, 1867, p. 251.

[3] Ramsay, 'Geol. of N. Wales' (*Mem. Geol. Surv.*), ed. 2, 1881, p. 297.

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and trilobites such as *Phillipsinella*, *Staurocephalus?*, *Cybele*, *Cheirurus*, *Chasmops*, *Lichas*, and *Agnostus*. These beds apparently represent the Dolhir Beds of Glyn-Ceiriog.

The highest beds are more arenaceous, and include in places hard grit-bands with occasional calcareous nodules, *e.g.*, just north of Moel-Frochas (north-west of Llanfyllin). These beds may represent the Glyn Grit of Glyn-Ceiriog.

SILURIAN.

The Llandovery-Tarannon beds of the Ceiriog district have not been found by Mr. King in the Llanfyllin region, where the Ashgillian is succeeded by graptolitic mudstones, possibly of Wenlock age. On Cefn-grugos (north-west of Llanfyllin), *Monograptus* has been found in some beds that underlie the grit shown on the old map (74 S.W.) as the base of the Silurian; and it is believed that this grit is of Wenlock age. A new outlier of Silurian, in which no grit appears, has been discovered on Moel-Frochas.

CARBONIFEROUS.

CARBONIFEROUS LIMESTONE SERIES.

The Carboniferous Limestone Series crops out westward of Oswestry, and has been surveyed by Mr. Wedd from Craignant in the north to Craig-y-rhiw, south-west of Llawnt, and again south of Llynclys; but the intervening part of the outcrop has not yet been re-examined. The series exhibits the following descending sequence:—

Carboniferous Limestone Series, near Oswestry.

(*c*) Sandy limestones, in part obscurely oolitic; calcareous sandstones, in places pebbly, with at least one band of strong quartz-conglomerate with a calcareous matrix; a few thin beds of sandy shale	Sandy Limestone Group. ? 500 ft.
(*b*) Grey limestones, some thin-bedded, others rubbly and shaly, with shale-bands in the upper part (near Craignant); a rubbly coral-bed, very persistent; near the base a band of calcareous shale full of limestone-nodules. Grey limestones, some thin-bedded, others more massive, constitute the bulk of the group.	Upper Grey Limestone Group. ? 100 ft.
(*a*) Limestones, cream and pale fawn-coloured, rather thin-bedded, some being of porcellanous texture; at Craig-y-rhiw about 20 ft. Basement-bed thin, sandy, and dolomitic, grey or brown, poorly exposed in the north.	Upper White Limestone Group. About 30 ft.

(*a*) The sandy basement-bed appears to have no connection with the 'red basement-beds' developed farther north at a much lower horizon.

The 'white' limestone at Craig-y-rhiw is assigned on lithological grounds to the upper part of the White Limestone Group of Denbighshire.

(*b*) These grey limestones agree closely with the Upper Grey Limestone Group of Denbighshire and Flintshire; the rubbly coral-bed may be continuous with the persistent coral-bed of those counties.

(*c*) A fairly well-marked change brings in the Sandy Limestone Group, but it remains uncertain whether this change takes

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place at the same horizon as in Denbighshire. A band of purple-spotted sandstone in the lower part, a gritty limestone full of quartz-pebbles somewhat higher, and some beds of obscurely oolitic sandy limestone still nearer the top, have been traced for some distance.

The limestones are not markedly stained or dolomitized until the southern part of their outcrop is reached, in the neighbourhood of a known outcrop of Bunter. At Lower Sweeney a fine-grained calcareous sandstone of the Sandy Limestone Group becomes increasingly dolomitized and stained as it approaches an outcrop of Bunter. About half-a-mile south of Llynclys Station some massive beds in the Upper Grey Limestone are highly dolomitized and more or less strongly stained in the neighbourhood of the Bunter outcrop.

CEFN-Y-FEDW SANDSTONE ('MILLSTONE GRIT').

The Carboniferous Limestone Series passes upward gradually into the Cefn-y-fedw Sandstone or supposed Millstone Grit, and Mr. Wedd has experienced much difficulty in deciding upon a line of separation between the two formations. The base of the 'Millstone Grit' drawn on the old map is certainly not a consistent stratigraphical line: it approaches comparatively close to the 'cherty beds,' below which, in Denbighshire, the lower sandstones and conglomerates of the Cefn-y-fedw Sandstone have a thickness of 250-300 feet. Yet the second scarp above this line, at Craig-Forda, contains a highly calcareous rock with crinoids.

The series, in descending order, can be tabulated as follows:—

Upper beds nowhere exposed.
Quartzose pebbly grits or sandstones.
Strata not exposed.
Cherty Beds:—Quartzitic sandstones, fine-grained; containing brachiopod-spines, *Spirifer*, small *Productus*, etc. In part these alternate with:—
Quartzose sandstones, with nodules and layers of pale-grey chert; bands of coarse conglomerate locally.
Quartzose sandstones, fine-grained, with pebbly seams: the lower beds probably pass laterally southward into calcareous sandstones.

The fine-grained cherty beds are readily correlated with Morton's 'cherty shales' of Ruabon Mountain, but his 'flinty shales,' which there occupy a higher horizon, have not been recognised in the south. On the other hand, the lower beds, with nodules and layers of chert, first seen half-a-mile north of Selattyn, have not been detected farther north.

COAL MEASURES.

Mr. Wedd finds that the Lower and Middle Coal Measures are everywhere covered with drift within the area surveyed near Oswestry. No collieries are at present working within the district, and the only exploration recently carried out consists of three borings at Daywall Colliery, Gobowen, the cores of which are being examined.

Red Upper Coal Measures, which should apparently be assigned to the Ruabon Marls, have been worked for brick-making at the Sweeney Brickworks, south of Oswestry. They

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are of the usual type of purple clay, with one or two thin beds of grey, apparently ashy, sandstone resembling the 'Espley Rock.'

An exposure of 'Permian' Sandstone, indicated on the old map near Croes-Wylan, on the south side of Oswestry, is now concealed, and the rock has been seen nowhere else. It may be presumed to belong to the Erbistock or Keele Beds.

Between Shrewsbury and Haughmond Hill the red Keele Beds overlying the productive Coal Measures of the Shrewsbury coal-field, and represented on the old map (61 N.W.) as Permian, have been found by Mr. Cantrill to be almost concealed by Glacial drift. The only good section so far discovered is that afforded by the banks of the Severn at Monkmoor, where purple-red flaggy sandstone, and purple, red, and lilac-coloured marls are exposed. Between Haughmond Hill and Roden a small area of brown sandstone free of drift has been detected at Somerwood, while white and crimson clay has been dug, and lavender-coloured sandstone quarried, in the valley of the Roden, north and east of Roden village.

A boring for water at Roden[1] proved, at the most only 17 feet of Keele Beds, under the drift and overlying the Longmyndian rocks (p. 6).

TRIAS.

LIVERPOOL DISTRICT.

In the portion of Lancashire falling within Sheet 96 the work has been carried on by Mr. Wray. The 'solid' formations mapped are the Pebble Beds and Upper Mottled Sandstone of the Bunter, and the Basement-Beds and Waterstones of the Keuper.

Pebble Beds.—The greater part of the Liverpool district is underlain by these beds, which occur in two north-and-south belts bounded by faults. A belt of Upper Mottled Sandstone shown on the old one-inch map between Walton Hall and Sefton Park has now been proved to have no existence. The Pebble Beds have been seen in borings at Walton Hall, and in excavations in Sefton Park.

Upper Mottled Sandstone.—The soft mottled crimson sandstone of this subdivision is well exposed in the Dingle cliffs, on the Mersey shore south of Toxteth Park. In addition, two narrow north-and-south strips have been proved by borings and excavations in the centre of the city. The western one extends from Bootle and Kirkdale to the neighbourhood of the Custom House; the other is faulted in between the Keuper of the centre of the city and the broad outcrop of Pebble Beds to the west. These beds, though usually soft and friable, contain harder bands near the top, like those noted in Wirral, and also in Shropshire.

Keuper Basement Beds.—At their base these are usually gritty, and contain small pebbles of quartz, quartzite, and marl. Well-records, however, indicate that these gritty bands are not confined to the base.

[1] Information kindly supplied by Mr. J. W. Nowell of the Co-operative Wholesale Society, Roden.

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A pebbly sandstone referred on the old map to the Bunter Pebble Beds is exposed between Dingle Lane and South Hill Road; by Morton it was identified as Keuper Basement-Beds, which, indeed, it more closely resembles. This identification also better accords with the occurrence of the Upper Mottled Sandstone with a northerly dip at the Dingle.

Keuper Waterstones.—As seen in St. James's Cemetery these beds rest on the Basement-Beds with a distinct plane of separation. They consist of red and grey shale with some bands of flaggy sandstone. Their total thickness is probably not more than 100 ft. Near their base a fossiliferous band[1] has yielded impressions of *Equisetites* and *Estheria*. Some of these exposures of the Waterstones have been referred to the Keuper Marl by Morton and other workers, but the presence of a fossiliferous band seems to link the beds in question more closely with the Waterstones.

SHROPSHIRE DISTRICT.

Bunter.—South of Oswestry Mr. Wedd finds that the Trias extends farther west than is shown on the old map. Lower Mottled Sandstone crops out at Weston Lower Mill, where a thickness of about 20 ft. of red sand-rock with the characteristic rounded grains is well-exposed in a sand-pit. It is current-bedded but appears to dip south-eastwards.

The rise produced by this Bunter outcrop is continued by a slight eminence on which Sweeney Hall is situated.

The strike thence trends in a south-south-westerly direction, toward another sand-pit on the western side of the main road north of Llynclys. The dip is probably easterly, at a slight inclination, and the sand is evidently banked against the slope of Carboniferous Limestone exposed in an adjacent quarry.

Another patch of Bunter comes to the surface about a mile east-south-east of Llynclys.

From the foregoing remarks it will be clear that the Bunter outcrop, with a general south-south-westerly strike, not only oversteps the Erbistock or Keele Beds (the 'Permian' of the old map), but transgresses on to at least the Sandy Limestone Group of the Carboniferous Limestone. Thus, whatever the relationship of the Erbistock Beds to the underlying Coal Measures, a strong unconformability marks the on-coming of the Trias, here as in North Denbighshire and elsewhere. Moreover, the south-south-westward strike of the Trias is maintained across at least one important northward downthrow, so as to suggest that such faulting is of pre-Triassic date. The local rapidity of the transgression is susceptible of ready explanation. For many miles northward all the strata have a general eastward dip, and the Bunter comes on regularly above the Erbistock Beds with no obvious discordance. But from Sweeney Mountain southward the Carboniferous rocks seem to have been uplifted anticlinally and faulted, sufficiently to have led to the cover of Coal Measures being removed and the Lower Carboniferous rocks partially denuded in pre-Triassic time.

[1] S. H. Pritchard, *Proc. Liverpool Geol. Assoc.*, n.s., no. 2, 1907, p. 16.

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The area surveyed in the Oswestry Sheet (137) by Mr. Wray includes the country south-east of Oswestry and extends to the southern limit of the sheet.

The Lower Mottled Sandstone west of Knockin consists of a deep-red thinly-laminated sandstone, with occasional white and yellow bands. These beds, which are soft and incoherent at the outcrop, and have been dug for moulding-sand, are entirely devoid of pebbles. In an old quarry at Osbaston the Bunter Pebble Beds rest on what appears to be an eroded surface of the Lower Mottled Sandstone.

The Bunter Pebble Beds are to be seen in numerous sections around Woolston and Knockin. They consist of coarse red sand and sandstone, in which small scattered pebbles are numerous, but are seldom congregated into definite pebble-beds; the presence of pebbles is the only means by which an exposure of this subdivision can be distinguished from one in the Lower or in the Upper Mottled Sandstone. The formation has a fairly uniform dip to the east, and is succeeded by the Upper Mottled Sandstone at Sandford. Hereabouts, the thickness of the Pebble Beds appears to be not less than 650 ft., on the assumption that there is no repetition by faults.

The suggestion made in last year's Summary (p. 17) that the Pebble Beds south-east of Oswestry extend slightly more to the west than is shown on the old map is supported by Mr. Wedd's discovery of Lower Mottled Sandstone to the south of Oswestry (p. 12), far beyond the limits shown on the old map.

At the western end of the village of Knockin the included pebbles are sufficiently abundant to constitute a true pebble-bed; they comprise white and pink quartzites, well-rounded pebbles of Silurian ashes and grits, together with some of chert and of Carboniferous limestone.

In passing eastwards across the outcrop of the Pebble Beds Mr. Wray finds evidence of a gradual transition from typical Pebble Beds with numerous pebbles at Knockin and Kinnerley to the non-pebbly Upper Mottled Sandstone farther east.

The Upper Mottled Sandstone is well exposed in numerous sections at Sandford, Knockin Heath, Dovaston and Bankfield. It consists of soft crimson and yellow false-bedded sandstones devoid of pebbles and indistinguishable in appearance from the Lower Mottled Sandstone. A distinctive feature of both the Lower and Upper Mottled Sandstones is that in the neighbourhood of faults and joints they are frequently hardened, such harder bands forming slight north-and-south ridges, parallel to the lines of fault.

Lower Keuper Sandstone.—The beds exposed in the old freestone-quarries at Haughton and Tedsmore, and shown on the old map as Lower Keuper Sandstone, consist of light-red fairly hard sandstone. Except for their greater regularity and hardness, they are not distinguishable from the Upper Mottled Sandstone, and, in an old quarry in Tedsmore Wood, they further resemble it in being traversed by oblique planes along which hardening has

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taken place. If they are of Keuper age their characters show, as also does the evidence of the Haughton deep boring described below, that in this district there is a gradual transition from the Bunter to the Keuper.

Keuper Marl.—The small tract of Lower Keuper Sandstone, overlain by Keuper Marl, at Haughton and Tedsmore, is represented on the old map as faulted against a wide spread of Upper Mottled Sandstone on the east. The supposed Upper Mottled Sandstone appears everywhere to be concealed by Glacial deposits of great thickness. But a recent fruitless boring for water, carried out by the Great Western Railway Company at Haughton sidings, 1½ miles south-east of Rednal Station, has thrown an entirely new light on the matter. From Mr. Wray's examination of what is left of the weathered cores, and from information supplied by the Great Western Railway Company,[1] it appears that, below the Glacial deposits, Keuper Marl, and not Upper Mottled Sandstone, was the first formation to be met with. The following is an abstract of the section:—

Boring at Haughton.

		Thickness. ft.	Depth. ft.
	Glacial sand and gravel	67	67
Keuper Marl.	Red marl with bands of sandstone ...	323	390
Lower Keuper Sandstone and Upper Mottled Sandstone.	White sandstone	10	400
	Red sandstone, soft, with white patches	525	925

The white sandstone is presumably the top of the Lower Keuper Sandstone. The beds below must be supposed to represent the remainder of the Lower Keuper Sandstone and some of the Bunter; but neither the sinker's record nor an examination of the weathered cores has enabled Mr. Wray to identify the plane of separation between them.

This boring suggests that considerable modification in the old map may here be necessary. The Lias outlier of Prees occupies the core of a syncline, the axis of which ranges south-westwards towards Haughton and Ruyton, but the existence of 100–200 feet of Drift over the intervening ground makes it impossible to say with certainty how far the Keuper Marl extends. At any rate it is certain that not a little of the ground formerly believed to be underlain by Bunter is underlain by Keuper Marl.

North of Shrewsbury Mr. Cantrill finds that the area of Upper Mottled Sandstone shown on the old map as faulted against the northern side of the Keele Beds is deeply buried under drift. Bright-red sand-rock is visible in a brook half-a-mile south of Battlefield, and at several points in a valley north of Sundorne Castle.

The supposed Lower Mottled Sandstone faulted against the southern side of the Coal Measures, Longmyndian rocks and Keele Beds, east of Shrewsbury, is likewise generally drift-covered, but red sand-rock shows up in a few places. These exposures appear to be succeeded by pebbly sandstones, formerly quarried in an outlier at Sugden and shown on the old map as Pebble Beds.

[1] Through the kindness of Mr. A. J. Churchward.

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GLACIAL DEPOSITS.

LIVERPOOL DISTRICT.

In this district Mr. Wray finds that red boulder-clay, with some interstratified sand and gravel, fills up the hollows between strike-ridges of sandstone. It contains shell-fragments and abundant boulders derived from the Lake District and the South of Scotland.

The re-survey has led to considerable modification of the drift-boundaries between Everton and the Mersey estuary. For example, the slope that rises from the estuary to Scotland Road appears to be overlain by boulder-clay averaging 50 feet in thickness.

SHROPSHIRE DISTRICT.

In the drift-covered area mapped by Mr. Smith on the south-western outskirts of Ellesmere, the most interesting feature is the composition of a belt in which sand and boulder-clay assume a hummocky form with the usual accompaniment of meres. The belt is about 2 miles wide, and runs across country from north-west to south-east through Welsh Frankton and Cockshutt. The material forming the hummocks has been derived from both northern (Irish Sea) and western (Welsh) sources.

North of this belt the drift consists of (1) a thick mass of pale-red stratified sand of northern origin, containing shell-fragments and occasional streaks and pockets of gravel, overlain by (2) a red boulder-clay also of northern origin, in which a few stones and boulders are present.

In the belt, while the same red sand (1) occurs as hummocks, it is frequently overlain by a boulder-clay of composite type. The more sandy portions of this clay appear to be of northern Triassic origin, while some of its hummocks are capped by small patches of gravel composed of débris from the Welsh hills, mixed with Triassic material of westerly origin.

For several miles south of the belt the same substratum of red sand appears to underlie a sandy reddish boulder-clay, as well as a clayey gravel of which the component materials are in the main of Welsh origin.

But while the description above holds good in the main, there has been some inter-crossing of erratics, *e.g.*, Lake District granite boulders have been seen in the Welsh gravel south of the morainic composite belt.

An interesting boulder, which gives the direction of transport of the Welsh drift, is preserved at Ellesmere College. It is a mass of Llandilo limestone, measuring 6 ft. across, which appears to have been derived from the outcrop at Craig-y-glyn, near Llanrhaiadr (p. 7). The direction of transport indicated is about E. 10° N.

In and on the borders of the Tanat Valley, south-west of Oswestry, the boulder-clay mapped by Mr. Smith is of a local type, with boulders derived solely from the Welsh hills; no sign of drift from the Irish Sea basin has been seen in the ground

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lying west of Blodwel Junction. Glacial striæ on the high ground point in an easterly direction.

In the Llanfyllin district Mr. King has noticed a similar type of locally-derived boulder-clay in the valley-bottoms. At Bodyddon-isaf (2 miles north-west of Llanfyllin) a mound of gravelly drift forms a barrier across a valley, not unlike a moraine. Glacial striæ, wherever observed, point down the valleys, *i.e.*, they indicate an easterly movement from the Welsh hills toward the plain of Shropshire.

In the Oswestry district Mr. Wedd finds that the northern drift and the local Welsh drift are both represented, the latter being the more extensive. In fact, except north of Whittington, the red northern drift is seldom seen at the surface; but it underlies the blue slaty Welsh drift in the borings of the Daywall Colliery at Gobowen, and fills a deep pre-Glacial valley west of Selattyn, where it contains abundant Eskdale granite-boulders and also shell-fragments. But a red tint does not necessarily imply a northern origin; for bright-red boulder-clay, apparently devoid of northern rock-fragments and shells, overlies the red Upper Coal Measure clays of Sweeney.

From the low ground north of Whittington, and the hills above Selattyn, quartzose sands and gravels extend southward to the neighbourhood of Oswestry Racecourse, where the shell-bearing gravels of the Glopa and other pits have long been famous. The lower eastward slopes of the hills are generally covered with Welsh slaty drift, partly unstratified, partly stratified into a dirty slate-gravel, especially toward the low ground on the east.

In the ground south-east of Oswestry surveyed by Mr. Wray, red boulder-clay of the Irish Sea type has been met with only in the village of Rednal, and south of the village the prevalent drift is of Welsh origin. No definite line can, however, be drawn between the two, as patches of Welsh drift have been found on the surface of the northern drift, and considerable commingling of material of both Welsh and northern origin has evidently taken place. This can be observed in a gravel-pit near St. Chad's church, Haughton, where deep-red sands, possibly in part of local origin, but no doubt largely derived from the Bunter outcrop to the north, are crowded with bands of pebbles of fossiliferous sandstones, limestones and ashes, all of Welsh derivation. No granitic boulders were noticed in the section, but shell-crumbs occur, though very sparingly.

At West Felton, Kinnerley and Edgerley, the boulder-clay is composed almost entirely of fragments derived from outcrops of Lower Palæozoic grits, sandstones and ashes. Some of these pebbles are fossiliferous, and appear to have been transported from the higher reaches of the Tanat and Vyrnwy valleys. Granite boulders and shell-fragments, such as would certainly have been met with had the material been derived from the north, are absent.

Associated with the boulder-clays are mounds patches of crimson sand, with pebbly bands. These gravels make ranges of hillocks, rising out of the lower ground. They probably also largely underlie the later glacial flood-gravels alluded to

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below, as well as protrude through them. They consist of exclusively Welsh material in a matrix of crimson sands derived probably from the local Trias.

For some miles north-east and east of Shrewsbury Mr. Cantrill finds that the Glacial deposits occupy most of the surface. Boulder-clay alternates with sand and gravel, though much of the boulder-clay might be described as a clayey gravel. What appears to be the lowest of the Glacial deposits is a stiff dark-red, purple, and chocolate-coloured clay, containing a few pebbles chiefly of slaty sandstones and grits of Welsh origin. In the lower ground between Shrewsbury and Battlefield this rests directly on the Keele Beds, from which it is probably to some extent derived. But that the Keuper Marl country to the north, about Wem and Whitchurch, contributed much of the material is evident from the fact that small pieces of 'skerry' are abundant in many of the sections. In one exposure shell-fragments have been noticed; while igneous boulders and Carboniferous limestone pebbles occur in others. No Liassic fragments from the outlier of Ightfield and Prees have, however, been observed. These characters point to a northerly and north-westerly source for the boulder-clay in question.

Thin beds of light-red loamy sand and sandy gravel overlie and are interbedded with the boulder-clay described above. These contain rarely a few flints; but the majority of the pebbles are of Welsh origin. The abundance of sub-angular débris of Longmyndian rocks on the surface of the country lying immediately to the south-east of Haughmond Hill affords additional evidence that the ice moved from a north-westerly region.

LATE-GLACIAL, POST-GLACIAL AND RECENT.

At one of the latest stages of the glaciation, while the last remnants of ice were melting, much flood-water appears to have been liberated. In its course from the uplands this water cleared out much of the drift in the mountain valleys and spread it out as a Late-Glacial flood-gravel along the lower reaches of those valleys, and also over the margin of the Shropshire plain, where it filled up many of the hollows in the surface of the drift and covered wide spaces. During this period it is evident also that the condition of the drainage in the lowlands was extremely unstable, and some of it probably remained so till the streams were brought under control by early agriculturists.

In the Tanat valley a well-marked terrace, standing at varying levels from 10 to 30 feet above the recent alluvium, has been traced downward from the western edge of the map. The terrace is sometimes cut in boulder-clay or in glacial gravel, sometimes in the 'solid' rocks, and is not always represented by terrace-deposits. Usually, however, it forms a well-marked shelf of roughly-stratified gravel, the composition and arrangement of which lead Mr. Smith to conclude that it was the work of Late-Glacial flood-water. These terrace-gravels follow the Tanat valley south-west of Llanymynech Hill into the Vyrnwy valley, where large areas of similar flood-gravels are spread out. They also enter a deep gap in the Carboniferous Limestone at Porth-y-waen, which may have been a pre-Glacial course of the Tanat.

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South and south-east of Oswestry, in ground surveyed by Messrs. Wedd and Wray, the valley of the Morda, after emerging from the hills, broadens greatly, and is occupied by a gravelly deposit, not distinguishable at its upper end from the alluvium, but at its lower end trenched by the stream. In this direction the gravel-flat seems to lose itself among islands of drift.

On the high limestone ground west of the Morda valley a sinuous dry channel takes its origin and, ranging south-eastwards, increases in depth by rapid steps until it nearly reaches the Morda valley. It appears to have been a temporary overflow channel for the waters of the Morda basin at some late stage in the glaciation, when the usual line of drainage was obstructed.

2.—Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.

E. E. L. Dixon, B.Sc.
C. H. Cunnington, B.Sc.
T. Eastwood, A.R.C.S.
T. H. Whitehead, B.Sc.
R. du B. Evans, B.A.
} Geologists.

The field-work during the year consisted in the continuation of the survey of the Carboniferous rocks and newer formations in the one-inch maps (sheets 153, 168, 169) which include the coal-fields of East Warwickshire and South Staffordshire. The small inliers of pre-Cambrian rocks near Stoney Stanton and Sapcote in Sheet 169 were also surveyed.

PRE-CAMBRIAN.

At Croft, Stoney Stanton, and Sapcote some of the oldest rocks known in the Midlands come to the surface in five isolated exposures. Croft Hill, the northernmost, rising abruptly to a height of over 100 ft. above the surrounding flat country, forms a conspicuous feature, reproducing in miniature the outline of the well-known pre-Cambrian massif of the Wrekin in Shropshire. About one and a-half miles to the south-west a broad ridge, trending north-west to south-east, rises above the lowlands bordering the valley of the Soar between Stoney Stanton and Sapcote. Its flanks are composed of boulder clay and Keuper Marl, which are plastered against, and, in places, over the same type of rock as at Croft; but, except in the large quarries at Stoney Stanton and Sapcote, exposures are limited.

The rocks of Croft and Stoney Stanton have been classed with the syenites and, though somewhat more acid, are considered by Professor Bonney[1] and by Professor Watts[2] to be of the same age as the pre-Cambrian syenites of Charnwood Forest.

The chief exposures at Croft lie outside the area surveyed.

[1] 'The Precarboniferous Rocks of Charnwood Forest,' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, pp. 229-30.

[2] 'The Geology of the Country between Atherstone and Charnwood Forest,' (*Mem. Geol. Surv.*), 1900, p. 9.

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In those of Stoney Stanton and Sapcote a pink syenite, varying slightly in shade and texture, predominates. There are also occasional thin layers of a bluish rock which is best seen in Cory Hill Quarry.

The conspicuous structural feature is a system of jointing, striking nearly due east and west, the joint planes dipping at 50° to 60° south with great regularity, thus producing a false impression of stratification. It is noteworthy that the bands of blue rock and the altered, crushed and often red-stained layers, called "rammel" by the quarrymen, have the same direction as the jointing. A less prominent, but still conspicuous set of joints, trends N. 37° E., dipping southwards at 80°. The pink stone is worked chiefly for setts: the tougher, grey rock for road-metal, of which the quality in Cory Hill Quarry is stated to be very good.

COAL MEASURES.

Warwickshire Coalfield.—The following grouping of the productive measures and of the closely associated overlying red and grey unproductive strata, already recognised in the northern and central parts of the coalfield, is applicable also to the southern end:—

			Thickness in feet.
Unproductive Series, 3,250 ft.	Upper Red Sandstones and Marls	Upper Group	750+
		Middle Group	1,000
		Lower (or Keele) Group	1,900
	Upper Grey Measures (Halesowen Group)		450
	Lower Red Marls (Etruria Marl Group)		150
Productive Series, 500 ft.	Lower Grey Measures		500

South of Hawkesbury Mr. Eastwood finds that the Coal Measures below the Keele Group are concealed either under Drift or Trias. Numerous old pits have reached the coals below and the records when available have been examined. The present workings of Binley Colliery prove the extension of the workable seams south-east of Coventry.

At Hawkesbury and Exhall Collieries, and also in the borings at Keresley and Whitmore (p. 21), the Thick Coal is practically one seam; but, south of Hawkesbury, it begins to split, and at Wyken (Alexandra) Colliery, 1½ miles to the south, it is represented by the Slate and Ell Coals, separated by 11 feet of fireclay. Farther south the distance apart of these seams increases. The Seven Feet coal, 90 feet below the Thick Coal, also appears to split up southward into several thin unprofitable seams.

At the old Wyken Colliery, one mile south-south-east of Hawkesbury, the record gives 60 feet of red measures lying 187 feet above the Two Yard Coal, and the same thickness of similar strata is mentioned as occurring at 174 feet above the Two Yard Coal at the Alexandra pits, half-a-mile to the south. The overlying Keuper Sandstone is nearly horizontal in both cases, but the red measures and the coals below dip west at

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1 in 4 (14 degrees). To refer these red measures to the Permian as was suggested many years ago[1] implies the local denudation of over 600 feet of measures, since within short distances to the north-east and south-east, the base of the Keele Group has been proved to be never less than 800 feet above the Two Yard Coal. It is more likely, then, that the red strata are either the upper part of the Lower Grey Measures stained red by percolation through the overlying Trias; or that, as is more probable, they represent the lower beds of the Etruria Marls, on the strike of which the shafts are situated.

The survey of the Upper Red Sandstones and Marls has been carried to the southern margin of the map (169).

The lower, or Keele Group, is poorly exposed. In the Middle Group the Exhall conglomerate has been traced by Mr. Eastwood for about a mile south of Exhall, chiefly by the presence in the soil of abundant pebbles of yellow chert and some of a grey limestone (probably of Carboniferous age). The Corley Conglomerate, mainly a dull red sandstone, with lenticles of conglomerate containing Silurian pebbles, some cherts, but rarely any of limestone, forms a well marked feature between Corley and Keresley. South of Keresley the outcrop is ill-defined, though it is still traceable through Coventry to Whitley Common. A good section, with the conglomerate exceedingly well developed, is seen at Radford, where the main road to Fillongley crosses the railway. It is also recorded in the borings for the Coventry Waterworks at Spon End and Whitley.

The highest beds of the upper red series occur around Tile Hill in the area surveyed by Mr. Cunnington, who estimates that they are 2,500 feet above the base of the Keele Group. They consist of bright red marls passing imperceptibly into marly sandstones. Thin conglomerate bands, containing pebbles of yellow chert and an occasional specimen of crinoidal limestone, are present; the best examples are exposed in an old quarry at Beechwood.

Whitmore Park and Keresley Borings (fig. 1, p. 21).—In the southern part of the coalfield sections of the Productive Measures, of the Etruria Marls, and of the Halesowen Group are seldom obtainable; while owing to changes in dip, coupled with false bedding, calculations as to the thickness of the Upper Red Sandstones and Marls, obtained from outcrop measurements, are not reliable; but the information is supplied by two borings put down by the Warwickshire Coal Company: one near Newland House Farm, Keresley, and a second near the Rifle Range, Whitmore Park, $2\frac{1}{4}$ miles south-east of Keresley. Permission to examine the material and also that of the shaft-sinking still in progress at Keresley has been kindly granted by Mr. W. P. Evans of Coventry.

Both borings commenced below the Corley Conglomerate, and were continued down to the Thick Coal, which was entered at a depth of 2,096 feet at Keresley and 2,421 feet at Whitmore.

[1] 'The Geology of the Warwickshire Coalfield,' (*Mem. Geol. Surv.*), 1859, pp. 21, 30, 31.

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They therefore afford direct measurements of the thickness of the Etruria Marls, Halesowen Group, Keele Group, and of more than half of the Middle Group.

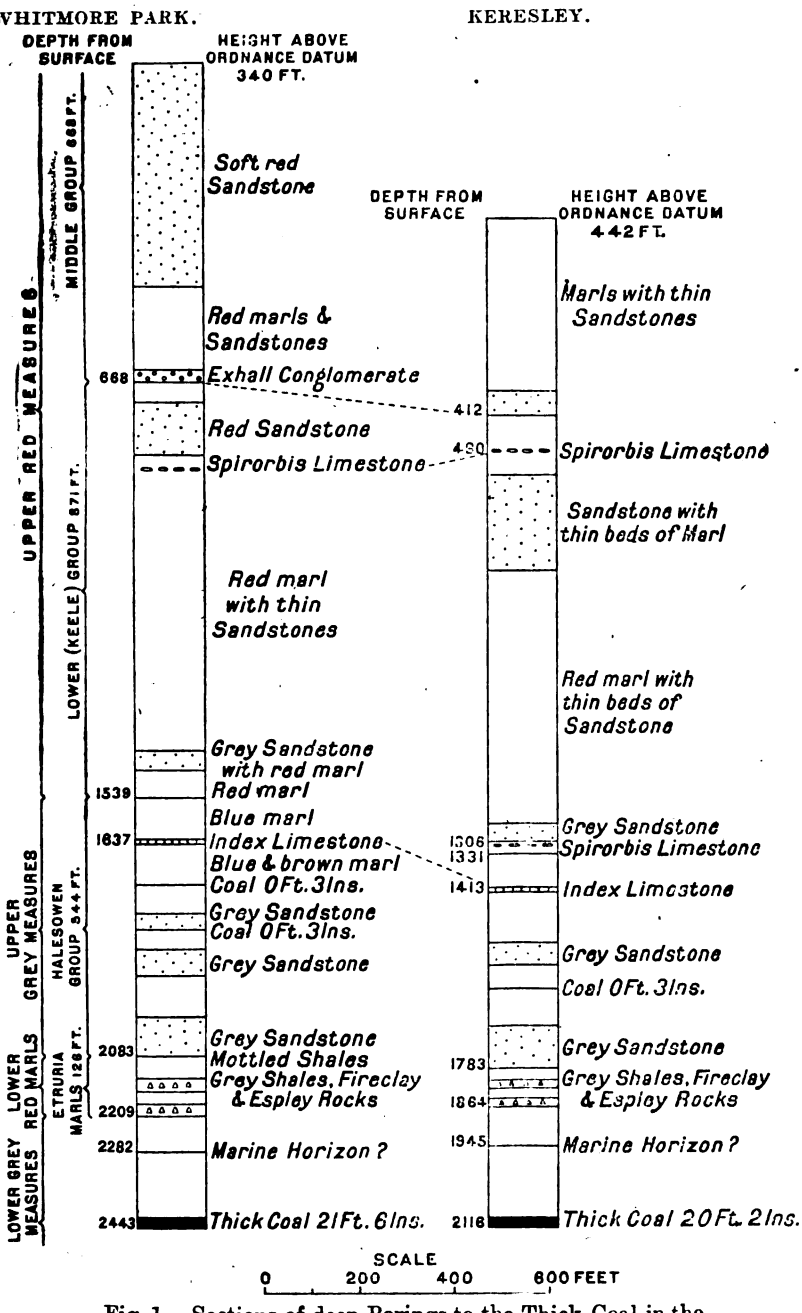

Fig. 1.—Sections of deep Borings to the Thick Coal in the Warwickshire Coalfield.

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The Thick or Main Coal, as the following sections show, contains only thin partings:—

Whitmore.

	ft.	in.
Coal	4	1
Parting	0	3
Coal	2	3½
Parting	0	1
Coal	4	1½
Parting	0	1
Coal	1	10
Fireclay	1	0½
Coal	2	4½
Parting	0	1
Coal	5	3½

Keresley.

	ft.	in.
Coal	2	1
Fireclay	0	4
Coal	11	6
Parting	0	1
Coal	5	2
Parting	0	1
Coal	0	11

The Keresley boring was carried down 57 feet, and the Whitmore boring 123 feet, below the Main Seam. A bluish-black shale, 5 feet thick, and 139 feet above the top of the Main Coal at Whitmore, was matched very closely by a band, 4 feet thick, at a height of 151 feet above the Main Coal at Keresley. The presence in each boring of this bed of a peculiar character, and the fucoid-like markings, suggest that it is one of the marine bands, but no shells were found in it.

It is difficult to recognise the beds below the Halesowen Group as the equivalents of the red Etruria Marls as developed at their outcrop. Except for an occasional bed of mottled shale, the whole group in each boring is grey and far more sandy than usual. However, the beds described as coarse sandstones in the records are of the same type as the Espley rocks seen in the red marls in the northern pit of the Haunchwood Brick Company. It should also be remembered that in most of the records of shaft-sections south of Nuneaton, beds in the position of the Etruria Marls are described as red and grey binds with mingled ground and coarse sandstones.

The Halesowen Group compares closely with the development at outcrop, but, in the Whitmore boring, contains more sandstone than usual, and the Index Limestone is slightly higher. The Index Limestone is much lighter in colour than the bands in the Keele Group, and *Spirorbis* is far more abundant. This is characteristic of the limestone over the coalfield, and, as its name implies, it forms a reliable index of the depth to the Thick Coal or its equivalents. The varying character of the Keele Group will be gathered from the illustrations (fig. 1, p. 21). It will be seen that the group is thicker in the north (Keresley) than in the south (Whitmore), thus agreeing with the general thinning out of the rest of the Carboniferous rocks in this direction. In mapping the district the base of the Keele Group was taken at the first bed of red marl above the essentially grey beds of the Halesowen Group. But in both of the borings grey sandstones occur above the first band of red marl. The rest of the sequence up to the Exhall Conglomerate or its horizon consists of bright red marls and dull red sandstones. Although the sandstones are frequently marly, and include beds of marl, while the marls contain thin sandstones, they can be grouped into rela-

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tively thick alternating beds of marl and sandstone. The nodular bed of Spirorbis Limestone at 490 feet depth at Keresley is probably represented by a bed found by Mr. Eastwood near Astley Court and by the limestone made up of brecciated fragments near Great Lynes Wood.

At the base of the Middle Group the Exhall Conglomerate in the Whitmore boring is identical in composition with that seen at Exhall (p. 20) and in the Keresley shaft at a depth of 440 ft., but it does not occur in the Keresley boring. In the beds above the conglomerate the borings show a great divergence in composition between the two localities.

South Staffordshire Coalfield.—A small area only has been surveyed in the Halesowen district, as shortly after entering upon it Mr. Cunnington left for military service. It appears that the well-known Clent Breccia at the base of the Bunter is stratigraphically separable from the underlying 'so-called' Permian, and is in many respects comparable to the Hopwas Breccia of the Tamworth district. In this connection it is of importance to note the occurrence in some borings at Saltley, of similar breccias below the Bunter Conglomerate, which thus form a connecting link between those of Clent, Sutton Coldfield and Hopwas.

TRIAS.

KEUPER.

The mapping of the Lower Keuper Sandstone, flanking the East Warwickshire Coalfield, has been completed by Mr. Eastwood. Its precise limits under the thick Drift cannot be determined, but there is no doubt that it gradually transgresses the older formations from north to south. Thus, at Marston Jabbett, it rests on Stockingford Shales, near Hawkesbury on the Lower Grey Group of the Coal Measures, and in the extreme south on the Corley Conglomerate. Whether, in places, the juxtaposition is due to faulting, as shown on the old one-inch map, is uncertain; but the cutting of the new loop line between Parting of the Heaths and Pinley shows that the Keuper here overlaps and is not faulted against the Keele Beds.

The Lower Keuper Sandstone consists for the most part of soft false-bedded micaceous sandstones of a grey or buff colour, with associated thin bands of red and pale green marl. Similar beds crop out around Coventry Station and between Warwick Road and Quinton Road; previously they have been placed in the so-called Permian, but their close resemblance to the local development of the Lower Keuper Sandstone and their apparent unconformity to the Corley Conglomerate (in a broad irregular hollow in which they were deposited) suggest that they are more likely of Keuper age. Sections occur at the eastern end of Coventry Station and in a sandpit in Stoney Road.

To the east of the sandstone-outcrop the Keuper Marl probably extends to the eastern margin of the map, except in the south-east, where Mr. Eastwood finds Lower Lias clays at the surface near King's Newnham. The Drifts, however, are so thick over the greater part of the area that the Keuper Marl

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seldom crops out. A stream on the south-west side of Coombe Abbey Pool shows red shaly marl with thin skerry bands, but elsewhere sections are poor and it is sometimes difficult to distinguish Keuper Marl from a red boulder-clay derived from it. To the north and north-east of Ansty, in the ground surveyed by Dr. Gibson, the marls certainly never come to the surface, but in the neighbourhood of the stone quarries at Sapcote and Stoney Stanton some interesting exposures, examined by Mr. Whitehead, have been laid open in quarrying the syenites. In a section along the tramline at the entrance to Lane Hill Quarry the marls assume a littoral character and consist mainly of soft even-bedded, deep red, very fine loams. Among these, thin bands of coarse grit, containing many small pebbles of syenite, are interstratified. Occasionally an isolated block of syenite is embedded in the loams. These strata are inclined at 8° north and rest directly on a highly inclined floor composed of the syenite. On the east side of the quarry an extremely coarse breccia bed, about 25 feet thick, occupies a shallow depression in the syenite. The breccia is mainly composed of pieces of syenite of varying sizes, cemented together by a calcareous cement. The rock has all the appearance of 'Head,' and is probably of Triassic age, though in the absence of any interstratified red marls this is not certain.

On the west side of the coalfield, south of Berkswell, Mr. Cunnington finds the Keuper Sandstone forming a narrow impersistent strip faulted against the Keele Beds on the east and dipping westwards beneath the Keuper Marl. It consists of pale brownish and white, soft, micaceous sandstones in the lower part and of sandstones with intercalated beds of marl in the upper part. Between Berkswell and Birmingham, it was met with at a depth of 475 feet, and penetrated for 225 feet in a boring at the Women's Hospital, Sparkhill. Here it consisted of massive grey and brown sandstones, with occasional pellety layers, showing characters intermediate between the white sandstones round the Warwickshire Coalfield and the red and brown type of the Birmingham district.

Between the Warwickshire Coalfield and Birmingham a large tract of Keuper Marl has been surveyed by Mr. Cunnington, north-east of Yardley and Hampton in Arden. Except in the south-east, round Berkswell and Balsall Common, where Keuper Sandstone emerges, the marl is everywhere faulted against older rocks. It is probably also traversed by a branch of the 'Western boundary' fault of the Warwickshire Coalfield, which cuts out part of the lower beds.

Near Birmingham, the marls dip persistently east and south, so that the 'Birmingham' fault brings in higher marl horizons as it is traced southwards. Thus at Bromford Bridge, in the north, a boring reached the bottom of the marls at 20 feet, while at Saltley, at the New Public Baths, George Arthur Road, and at the Metropolitan Carriage and Wagon Works, the Keuper Sandstone was touched at 124 feet and 128 feet respectively. South-east at Sparkhill (the Women's Hospital), and at Small Heath (Public Baths), thicknesses of 475 feet and

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413 feet have been recorded. The highest beds of the Keuper Marl may, therefore, be expected to occur round Coleshill, Little Packington, and Hampton in Arden, and it is significant that in each of these places sandstones and bluish marls of the Arden-Sandstone type have been met with. The Arden Sandstone is recognisable in a series of outcrops, disconnected in consequence of the replacement along the strike of the characteristic blue marls by red marls, and of coarse sandstone by the finer grained skerries. The most westerly point reached by the group is Stechford and over the county east of this, outcrops are frequently seen. Near Rytons End the sandstone has yielded a small fish-tooth.

GLACIAL.

Except in the south-west the high ground of the central part of the Warwickshire Coalfield separates a region in the east covered with 'Eastern' drifts from one in the west occupied by 'Western' drifts.

During the year the survey has been extended over parts of both areas. It has been found that the evidences of glaciation, as shown by glaciated pebbles and ice-grooved rock-surfaces, are far more numerous in the east than in the west. Thus, on an area of exposed syenite, eight square yards in extent, from which the surface-soil had been removed at Sapcote Quarry, Mr. Whitehead observed several deeply-cut grooves having a north-and-south direction. A moutonnéed and polished surface of syenite has also been uncovered at Lane End Quarry, Stoney Stanton. The striæ, though much fainter than at Sapcote, are again directed north and south.

Eastern Drift.—East of Nuneaton and Coventry a belt of low ground, about 300 feet above sea-level, is overlooked by a plateau reaching an elevation of over 400 feet. This plateau, composed of glacial sands and clays, is dissected by the Soar, Anker, Smite and Swift, tributaries of the Trent and Avon, into broad, and often, deep valleys. So far as ascertained, the glacial beds descend below the bottom of the deepest valley, but on the low ground at the foot of the plateau the solid formations, though still largely concealed by drifts, emerge at intervals.

The 'Eastern' drifts are separable, according to their composition, into:—

(1) An upper series of laminated, silty brown clays, with interstratified sands and gravel; upwards of 200 feet.
(2) Lower red clays, usually unstratified and of restricted occurrence; upwards of 30 feet.

(2) Around Stoke and Walsgrave the lower clays are found by Mr. Eastwood to be stiff and purplish-red in tint, with thin lenticles of sand and loam, lying on a highly irregular surface of Trias. Stones, as a rule, are not numerous, but in red clay, excavated to a depth of 25 feet at Stoke Hill, there is an abundance of large flints, together with pieces of skerry, limestones of various ages (Carboniferous? Lias, Oolite), and fragments of syenite, many of the stones showing striæ. Several well-preserved fossils (*Lima*, *Gryphæa*, Belemnites, Ammonites) have been collected by the workmen. A thick and wide-spread sheet of the upper brown

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clays extends over the country to the north and north-east, but the red clays, 0–3 feet thick, are exposed in the Top Quarry, Stoney Stanton, under an irregular cover of chalky boulder-clay. The best section was observed by Mr. Whitehead in the clay-pits near Broughton Astley, 2½ miles S.E. of Stoney Stanton. Here a stiff red clay, mottled pale green, especially the upper 10 feet, is worked for bricks to a depth of over 30 feet. The resemblance to Keuper Marl is close, and is accentuated by the inclusion of skerry-fragments, but numerous Bunter pebbles, pieces of limestone (Carboniferous?), fragments of sandstone and pebbles of syenite, many clearly striated, scattered through the body of the clays, betray its Glacial character. On the west side of the pit these red clays appear to be overlain obliquely by a chalky boulder-clay, but slips obscure the junction.

(1) The upper clays and sands, which cover nearly one-half the area of Sheet 169, are well-stratified deposits. The clays are generally of a brown colour, though occasionally mottled, and are nearly void of pebbles. A boring for water at Cloudesley Farm gives the following descending sequence:—Clay, 51 feet; sand, 66 feet; clay, 42 feet; sand, 38 feet; clay with stones, 4 feet. This may be regarded as an average sequence, but the sands frequently contain lenticles of clay, and the clays, wisps and irregular patches of sand. Gravel beds, made up largely of flints and Bunter pebbles, are generally associated with the sands; two fairly persistent and mappable bands are noted by Mr. Eastwood to occur, one at 250 feet O.D. and another at 300 feet O.D. around Walsgrave, Shilton and Harboro Magna. The one at 250 feet contains flints and Bunter pebbles, and that at 300 feet pebbles of Jurassic limestones in addition. A persistent band of gravelly sand has been traced by Mr. Whitehead for a distance of three or four miles from Dunton Bassett, through Leire and Frowlesworth. Its base falls somewhat rapidly towards the west from 480 feet O.D. at Dunton Bassett to 350 feet at Leire, which level it maintains to Frowlesworth and beyond. The main water supply of the villages is obtained from the sands and gravel. The water is usually abundant, but hard, and liable to contamination.

South of Tile Hill Mr. Cunnington finds Drift of Eastern type in a small patch near the railway station.

Western Drift.—Between Coleshill and Saltley the drifts, which cover considerable areas, consist of bedded sands and gravels, locally covered by a red pebbly clay.

On the west side of the South Staffordshire Coalfield Mr. Dixon has commenced the survey of the drift-covered low ground lying at the foot of Cannock Chase about Penkridge and Otherton.

The superficial deposits may be grouped better by their relationship to the existing drainage system, than by such slight differences in composition as can be observed:—

(1) Spreads of gravelly material with much clay in places, seen around Teddesley Park and south-west of Otherton, which extend down the eastern tributary valleys of the Penk, and end about stream level. They are evidently the latest of the drifts, and may represent late-glacial or fluvio-glacial outwash plains or morainic aprons from the Cannock Chase region.

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(2) Deposits of gravel and sands restricted to the Penk Valley. Flints in the condition of large battered pebbles are an interesting constituent. They differ from the angular and sub-angular flints of the 'Eastern' drifts, and are not unlike beach-pebbles.

(3) Unstratified material consisting of Bunter pebbles, far-travelled stones and re-arranged Keuper Marl. This type constitutes the bulk of the drift of the region, forming a mantle of irregular thickness over the inequalities of the ground on the east side of the Penk. It is broken through in two places by Keuper Sandstone, and on the west side it does not greatly obscure the contours of the solid rock.

(4) Small patches of sand and gravel, capping knolls east of the Penk and north of Penkridge, bearing little or no relation to the present valley system.

3.—London and S.E. District.

G. Barrow, District Geologist.

R. L. Sherlock, D.Sc.
H. Dewey.
C. N. Bromehead, B.A.
R. W. Pocock, B.Sc.
} Geologists.

In the London District the mapping has been continued in an easterly direction on both sides of the Thames. On the southern side Mr. Dewey has mapped the ground between Bickley and Downe on the west and Longfield and Kingsdown on the east; farther north Mr. Bromehead has carried on the work as far east as Dartford and Sutton-at-Hone; the survey was completed up to the Thames till the neighbourhood of Erith was reached, but was suspended in the ground at and below that town for military reasons.

The area surveyed on the northern side of the river extends for some distance to the north and south of the River Lea, in the neighbourhood of Hatfield and Hertford. North of the Lea, Dr. Sherlock has mapped the ground east of the Great Northern Railway as far as Collier's End and Ware; south of the Lea, Mr. Pocock has carried on the work eastward of Hatfield and South Mimms almost to the new railway between Cuffley and Hertford.

CRETACEOUS.

South of the Thames.—The boundary between the Middle and Lower Chalk has been traced by Mr. Dewey in the area surveyed by him. The Lower Chalk is seen only in the railway cutting between Otford and Shoreham. Here the pale-green marls belonging to the *Actinocamax plenus* Zone and dipping north at 5° are easily recognised; beneath them is soft white chalk with *Rhynchonella mantelliana* (J. de C. Sow).

The Melbourn rock at the base of the Middle Chalk has been met with in several places. It resembles the hard chalk (almost limestones) of the *Holaster planus* Zone, and consists of hard, cream-coloured nodules of chalk set in a matrix of soft chalk. The outcrop is marked by an abrupt change of slope.

The chalk-rock of the Planus Zone can also be traced by a similar feature.

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Nearly the whole thickness of the Upper Chalk is exposed in the cuttings of the Maidstone branch of the South-Eastern and Chatham Railway; these show that fossils are most abundant near the middle of the *M. cortestudinarium* Zone, and also near that of *Holaster planus*. The characteristic fauna which accompanies *Heteroceras reussianum* in the Planus Zone has been found by Mr. Dewey at many new localities, affording further evidence of its continuity between Kenley and the Medway Valley, where it has been described by Mr. G. E. Dibley.[1]

The whole of the chalk mapped by Mr. Bromehead belongs to the Zone of *Micraster coranguinum*. A narrow but continuous new outcrop of chalk much obscured by downwash of Tertiary Beds has been found to exist along the foot of the hill overlooking Plumstead and Erith Marshes. The downwash was formerly regarded as rock *in situ* and to explain its position a fault was shown on the former map and indeed on most geological maps of the district. The idea that a fault occurred here was strengthened by the boring at Crossness, where the top of the chalk lay at so much as 144 ft. below the surface, but the depth has now been proved by other borings to be due to dip. Similarly near Ruxley, south-west of Foots Cray, two parallel or trough-faults are shown on the former map to explain the supposed occurrence of a narrow strip of Tertiary Beds *in situ*. These also have been shown by a small excavation to be debris from the hill above.

North of the Thames.—Such little really bare chalk as has been met with on either the northern or southern sides of the Lea valley appears to belong to the Zone of *Micraster coranguinum*, which in this district is markedly unfossiliferous.

TERTIARY.

THANET SAND, WOOLWICH AND READING BEDS AND BLACKHEATH BEDS.

South of the Thames.—The Thanet Sand is well exposed over much of the area mapped by Mr. Dewey, especially along the railway cuttings between St. Mary Cray and Swanley Junction, where it may be as much as sixty feet in thickness. Obscure traces of fossils occur in one section near Swanley Junction.

In the Woolwich Beds masses of shells, chiefly species of *Corbicula* and *Melania*, form a continuous bed between Farnborough and St. Mary Cray. The Blackheath pebble-beds lie in hollows cut in the Woolwich Beds and the Thanet Sand, and even reaching down to the chalk. Between Green Street Green and Crockenhill the pebble beds form a series of outliers resting directly on the chalk, without any trace of the Woolwich Beds or Thanet Sand.

Evidence has been obtained of a slight movement which affected the Chalk before the deposition of the Thanet Sand. Thus all the Chalk bordering the Thames between Erith and Gravesend belongs to the Zone of *Micraster coranguinum*,[2] while five miles

[1] *Geol. Mag.*, 1912, pp. 372-374.
[2] Dibley, G. E., *Proc. Geol. Assoc.*, vol. xvi, pp. 484-496.

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to the south, between Orpington and Swanley, the Zone of *Uintacrinus* underlies the Thanet Sand, and at Farnborough that of *Marsupites*, South of Farnborough, at Keston, the Corauguinum Zone again crops out below the Thanet Sand; while a few miles to the east, at Well Hill, the topmost bed of chalk is probably low down in this zone, or even in that of *Micraster cortestudinarium*.

North of the Thames.—There are few clear exposures of the Reading Beds on the north side of the Lea valley, and the limits of the outcrops are difficult to determine. The work of Dr. Sherlock shows that there must be considerably less Tertiary material present *in situ* than the former map suggests. About Datchworth, for example, there can be but a small patch, in the immediate vicinity of the church. It is completely dissociated from the large drift-covered outcrop about Burnham Green and Bramfield. In this there are only two clear exposures; the first extends in a long narrow strip almost from the Green southward to the rifle range, while the second occurs in an isolated patch to the south-east of Datchworth Green where the clay and loam have been worked for brick-making.

There must be a fairly large and continuous outcrop between the Beane and the Rib, extending from Sacombe to Collier's End, not as formerly supposed two separate outliers.

On the south side of the Colne and the Lea, though much of the escarpment of the Reading Beds is free of drift, there are few sections. The large pit at Hatfield Park, described in the 'Geology of London,'[1] is now much obscured. Smaller pits near Rabley Park, and in the Mimmshall Valley, show that there is usually some nearly white sand at the base of the division.

On the opposite side of the plateau, within the Northaw inlier, all the old openings are now obscure; they mostly showed a considerable thickness of the sands resting on the chalk. In the valley south of Newgate Street, there is quite a chain of swallow holes into the chalk and about these the sands are often obscurely seen, accompanied in some cases by blocks of pudding-stone. One of these holes, a nearly circular pit, where the ground seems to have bodily caved in, shows 5 feet of loamy sand and clay with a band which contains teeth of sharks and casts of lamellibranchs. A foot below this band discontinuous patches of pudding-stone occur in loamy clay; each mass appears to rest in a slight depression in clean sand, the latter passing down into laminated clayey sand. The whole depth of the section is about 15 feet. The occurrence of the lamellibranchs recalls the section at Ayot described in the 'Summary of Progress for 1913,' p. 32. They are too fragile, however, for extraction. Mr. Pocock finds that the area occupied by the Reading Beds in the Northaw area is considerably larger than that shown on the former map.

LONDON CLAY.

South of the Thames.—Mr. Bromehead has mapped the outlier of the Claygate Beds on Shooter's Hill that was found by Mr. A. L. Leach; it is mostly concealed beneath the high-level gravel. As the base of the London Clay, both to the north and south of

[1] 'Geology of London' (*Mem. Geol. Surv.*), 1889, pp. 204-5

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the outlier, is about 180 feet O.D., and the top of the hill is only 420 feet, it appears at first as though there were not sufficient height of ground to include the Claygate Beds, but a boring at Lower Kidbrook to the west of centre of the hill has proved the existence of a syncline in which the base of the London Clay descends to 60 feet O.D.

In mapping the district considerable assistance has been given by Mr. A. L. Leach, who has noted the temporary sections for some years past, and has kindly placed his information at the disposal of the Survey.

North of the Thames.—An outlier of Claygate Beds which had been noticed by Mr. Barrow on a hill half-a-mile south-west of Willesden Green Station has been examined by Messrs. Pocock and Pringle.

The section now exposed in a brickpit shows about 12 feet of well-laminated clay with sandy seams. These deposits are yellowish-brown to grey, and rest on dark bluish-grey sandy clay which appears to be the top of the London Clay proper.

About a foot above the dark clay there are occasional septarian nodules which have yielded the following fossils:—

Plant-fragments [abundant]; *Hemiaster branderianus* Forbes; *Membranipora eocena* Busk; *M. sp.; Nuculana sp.; Protocardia nitens* (J. Sow.) [abundant]; *Teredo antenautæ* J. Sow. [abundant]; *Natica sp.; Pleurotoma sp.; Voluta nodosa* J. de C. Sow.; *V. sp.;* and a species of *Dentalium* which has not been preserved.

PLEISTOCENE.

South of the Thames.—Clay-with-flints of a reddish tint and containing large white-coated unworn flints, extends over the greater part of the chalk tableland as far as the crest of the escarpment overlooking Kemsing, where unworn flints are still abundant, although the clay here rests on the flintless Middle Chalk.

On many of the spurs of the north-end of the tableland more stony material is met with in which Tertiary flint-pebbles are abundant, and Greensand, brown-coated flints and vein-quartz become more common. The matrix varies from loam to sand, and much of it is derived directly from Tertiary Beds. In a southerly direction this deposit seldom occurs on ground higher than 500 feet O.D., except in the vicinity of Tertiary outliers, as at Kingsdown.

Several patches of high-level gravel containing chert and vein-quartz, water-worn flints and some Tertiary pebbles have been met with at Well Hill at heights of over 600 feet O.D. It has been suggested that the deposit is of Pliocene age, but no conclusive evidence has yet been found to support this view.

On Shooter's Hill, as noted by Mr. Bromehead, the high-level gravels form a small local plateau, their average thickness being about 10 feet; the base is not even, but has, on the whole, a low general slope to the north. The occurrences of these gravels in the south of the Thames are now markedly isolated, the nearest met with in the previous survey being at the Crystal Palace. These gravels contain no Bunter pebbles and no material that could not have come from the south side of the Thames.

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North of the Thames.—The general fall of the ground in the Lea Valley seawards is found by Dr. Sherlock to be accompanied by a complete disappearance of the more locally formed Clay-with-flints. The drifts on the north side of the valley all contain far travelled material, and the clay is of a chalky character. On the higher ground alone, as about Datchworth and Bramfield, it consists mainly of debris of the Reading Beds, associated with chalk-flints, and even here some foreign material is included.

The clear sections laid open along the new line from Hertford to Stevenage[1] have been further examined. These confirm the impression previously obtained from other parts of the area that, broadly speaking, the main mass of the Chalky Boulder Clay is superimposed with a junction of striking evenness upon the sands and gravels with Bunter pebbles which in turn rest on the chalk. But at Watton-on-Stone Dr. Sherlock finds a lower bed of chalky boulder-clay underlying the main mass of gravel and probably resting directly on the chalk. In several sections lenticles of clay have been observed within the gravel. At the well-known pit at Hertingfordbury a considerable mass of Chalky Boulder Clay overlies a thick deposit of sand and gravel, the latter resting directly on the chalk; only a short distance across the road clay is seen with gravel both above and below it. In the neighbourhood of Ware the more complicated sequence given below can be determined, though the whole does not occur at any one spot:—

6. Chalky Boulder Clay.
5. Sand and gravel, in lenticles.
4. Laminated clays, alternations of sand and clay.
3. Chalky Boulder Clay in lenticles and always thin.
2. The main mass of sand and gravel.
1. Tough Chalky Boulder Clay.
   Chalk.

All the above, except No. 1, are exposed in the old pits of the Ware Brickfields Company, situated in the north bank of the Lea, about half a mile north-north-west of Ware; No. 1 and the finest sections of No. 2 are seen only in the large pit by the side of the Watton Road, near the town.

(1) Beneath the gravels at the latter pit is some exceptionally tough, chalky boulder-clay, with an upper surface so uneven, as to suggest that the material was hard and had been deeply eroded before the overlaying gravels were deposited. It has not been seen at the eastern end of Ware.

(2) The main mass of sand and gravel at this pit is locally capped by the laminated clay, No. 4, and its full thickness must be at least 40 feet. The gravels have yielded many fragments of igneous rocks, including a block of typical laurvikite, found some years ago by Mr. Lamplugh, and a specimen of closely allied rock from the same district, found by Dr. Sherlock, who has also collected several specimens of crystalline schists.

There is considerable variation in the texture of these sands and gravels in different parts of the Lea valley; near the base they are locally fine and consist mainly of sand. This phase is

[1] A description of these sections as exposed up to May, 1914, is given by the late William Hill, in the *Proc. Geol. Assoc.*, 1914, vol. xxv, pp. 288-291, pl. 38.

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best shown in the pit near Cole Green, close to the Hertford and Hatfield railway. Bands of specially fine sand have been found by Mr. Pocock low down on the south side of the Lea valley in pits near How Green and Water Hall, to the west of Bayfordbury. They contain much comminuted soft chalk and well preserved foraminifera, identified by Dr. Sherlock as Cretaceous forms.

(3) That lenticles of chalky boulder-clay should occur between the main mass of the gravels and the laminated clays is unusual; and they are of additional interest as yielding blocks of far-travelled material. Among these Mr. Allen has recognised, on fossil evidence, Lower and Middle Lias, Portlandian and Lower and Middle Chalk; on lithological characters, fragments of soft red Triassic Sandstone, Spilsby Sandstone, Lower Greensand, Sarsen, etc., have been identified. They include also a number of igneous rocks not yet determined, as well as the abundant Bunter and Reading pebbles and chalk-flints. The chalk-floor, in the one spot visible beneath the sand and gravels, is stained yellow and hardened to a depth of 2 inches.

(4) The laminated clays have not so far been found in association with the far-travelled drifts. They are fine-grained deposits, generally stoneless, except for lines of small pebbles, and appear in some places to have been deposited in hollows in the pre-existing drifts. Where covered by chalky clay their upper limit is sharply defined, but where sand and gravel lie next above them, there seems to be an upward passage. They have been worked at intervals as far as the east end of Ware, and may occur farther north.

The character of these clays and the presence of fine-grained sands farther west, as described above, support the possibility of a small glacial lake having had a temporary existence in this part of the valley.

(5) The temporary nature of the lake is shown by the occurrence of the lenticles of sand and gravel into which the laminated clays graduate. Such deposits point to the breaking-down of the barrier by which the flow of the water had been arrested.

(6) The Chalky Boulder Clay, as seen at the Brickpit, does not differ markedly from the gravels in its contents. Large numbers of lumps and pebbles of chalk with many flints are associated with many pebbles foreign to the district. A mass cut open along the railway between Langley Sidings (near Stevenage) and Stapleford is therefore unusual in containing scarcely any flints and not many other stones, though rounded fragments of hard chalk are abundant. The dominant constituent seems to be the Oxford and Gault clays which became involved in a lobe of ice entering the district through the Stevenage gap. This type of boulder-clay occurs about the railway for some 5 miles, but its full extent has not yet been ascertained.

To the south of Hatfield Mr. Pocock has examined a rudely triangular plateau, mostly about 350 feet above sea-level, but locally rising to slightly over 400 ft. The western edge of this high ground overlooks the Colne Valley, and is formed by the Tertiary escarpment. For some distance this feature trends

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roughly in a north-easterly direction and rises above the limit of the far-travelled drift; but at North Mimms it turns due north and is now penetrated by the Chalky Boulder Clay. The clay largely fills a valley to the north-east of the village, draining northward and cut through the Reading Beds, and has been proved by a well to be 44 feet thick at one point (a third of a mile north of Parsonage Farm); it rests on 5 feet of a clean 'ballast' (gravel) which is separated from the underlying chalk by 9 feet of reddish loam and flints. The gravel crops out from beneath the clay at several points and is the normal Bunter-pebble gravel.

At Hatfield the escarpment trends from west to east and for a space again runs above the limits of the far-travelled drift; but about two miles east of the town it is a second time crossed by the boulder clay. The highest of several patches of varying size has penetrated well into the London Clay area and reached the crest of the northern and slightly lower part of the plateau; there it overlies a modification of the special type of high-level drift, characterised by abundant white quartz-pebbles which was described in the 'Summary of Progress for 1913,' p. 33. Between these patches of Chalky Boulder Clay Mr. Pocock finds the ground strewn with pebbles of foreign material, from which it may be inferred that the clay once covered a considerably larger area than now; indeed remnants of this drift are common over the plateau eastward of the Great North Road, between Hatfield and the north end of Barnet.

Chalky Boulder Clay has been met with at intervals on the summit of the plateau to a little southward of Potters Bar. In all these cases it rests at one spot or another on the gravel containing abundant small white quartz-pebbles. In no case, however, does it completely cross the plateau and descend into the Colne Valley. It seems clear that the boulder-clay in that valley entered it by the low divide near Hatfield.

The southern high-level drift described in the 'Summary of Progress for 1913,' p. 33, as covering nearly all the ground which rises above 400 feet in the southern area, and as containing abundant small pebbles of white quartz, has been traced eastward by Mr. Pocock to High Barnet and northward towards Hatfield. South of a line drawn from near Barnet towards Little Berkhampstead it contains chert fragments from the Lower Greensand in fair abundance, but to the north-west of this line chert is less common. Towards Barnet this white quartz pebble gravel maintains its high level and is free from admixture with far-travelled material, such as Bunter pebbles. In a northerly direction it retains this character as far as Potters Bar, where for the first time it is overlain by Chalky Boulder Clay. But, as the Hatfield area is approached and the ground falls, Bunter pebbles enter into its composition; at first apparently in the upper layers only, but later throughout, as may be seen in a pit near Bell Bar. But even here the abundance of white quartz-pebbles distinguishes the deposit from the normal widespread Bunter-pebble gravels, and the exact relations of the two have not yet been ascertained, further than they both lie below Chalky Boulder Clay.

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(B.)—SCOTLAND.

The field-work in the Highlands was arranged in two districts as follows:—

(1) West Highland District under Mr. C. T. Clough, M.A.
(2) North and Central Highland District under Mr. L. W. Hinxman, B.A.

The Coal-field revision was also carried on in two districts.

(3) Ayrshire (Kilmarnock District) under Mr. C. T. Clough, M.A.
(4) Renfrewshire and South Lanarkshire District under Mr. L. W. Hinxman, B.A.

1.—West Highland District.

C. T. Clough, M.A., District Geologist.

E. B. Bailey, B.A.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, B.A.I.
G. V. Wilson, B.Sc.
} Geologists.

The mapping of Sheet 44 of the one-inch map has now been completed, and, in addition, small portions of the neighbouring Sheets 43, 51 and 52 have been surveyed this year.

LOWER OLD RED SANDSTONE.

Lorne.—The Lower Old Red Sandstone rocks of the Oban district may be roughly divided into two groups—the lower sedimentary—and the upper volcanic. Dr. Peach, in the Survey Memoir dealing with Oban and Dalmally, has already shown that eastwards from Oban the sediments thin out rapidly against an original upland of slate, so that the overlying lavas come to rest more or less directly upon the slates. In the Loch Feochan district to the south of Oban Mr. Bailey finds that the Oban basin of accumulation can be traced without any decrease of depth, though the infilling consists almost entirely of lava flows. In fact, the lower lavas of Loch Feochan are contemporaneous with the thick conglomeratic series of Oban and Kerrera. The conglomerates, it may be recalled, contain from 75 to 100 per cent. of rolled fragments of lava; no doubt these pebbles and boulders were derived from lavas accumulating on the neighbouring upland.

TERTIARY IGNEOUS ROCKS.

Western Mull.—Intrusive sheets distinctly chilled at their margins, and consisting partly of pitchstone, are not uncommon among the plateau-basalts. They extend, Mr. Clough states, as far west as the Bunessan fault which forms the south-west boundary of the lavas. These sheets frequently contain highly altered sapphire-bearing xenoliths, like those described in the 'Summary for 1912,' pp. 48, 66. Small xenoliths of graphite are also occasionally seen. The most western locality at which sapphires have been observed lies about 50 yards from the coast, nearly half a mile west of Ardchrishnish.

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North of Loch Scridain.—Sapphire-bearing intrusions have been noted by Mr. Anderson along the course of the Allt a' Mhuchaidh, near the foot of the Abhuinn Bail' a' Mhuilinn, and on the shore both east and south-west of Tiroran. The three last are probably separated exposures of a single sill, which in places consists partly of pitchstone.

Ben More.—The igneous rock described in last year's 'Summary' (p. 46) as occurring to the north of Ardvergnish, and strongly resembling trachyte, has been determined as mugearite by Dr. Thomas. The same applies to the 'trachytic' intrusion on the south-east flank of Ben More, which was referred to as being later than a north-west dyke. Starting somewhat abruptly in the Coir' Odhar, the latter mugearite forms a flat sill whose outcrop has been traced by Mr. Anderson and Mr. Richey almost entirely round the Ben More-A'Chìoch mass, with a maximum thickness of about 300 ft. It is cut by numerous minor intrusions, some of which belong to the A'Chìoch group described in last year's 'Summary' (loc. cit.). It dies out finally, no less abruptly than it appeared, on the steep eastern slope of A'Chìoch.

Tobermory.—The country west of Tobermory is chiefly built up of a succession of almost flat flows of fine-grained olivine-basalt. Mr. Wilson found a number of small dolerite plugs along a line striking north-west. The most interesting of these, forming the hill of 'S Aìrde Beinn, was described many years ago by Professor Judd,[1] and more recently by Sir A. Geikie.[2]

Central Mull.—The portion of Mull which falls within Sheet 44, and includes the whole central complex, has now been examined. The completion of the field work has led to clearer conceptions in regard to several of the issues raised in previous 'Summaries,' and we shall here discuss some of these points in succession.

(1) Loch Bà Felsite Dyke.—The Loch Bà dyke was originally traced by Sir A. Geikie from Glen Forsa to Beinn nan Gabhar.[3] Its outcrop in this part of its course is shown on a map by Mr. Wright ('Summary of Progress for 1910,' Fig. 1), which illustrates the interesting fact that the dyke follows the course of a curving fault already partly described in the 'Summary for 1909,' p. 32. In the 'Summary for 1913' (Fig. 6, p. 49), Mr. Richey showed that the dyke, after a short interruption, reappears south-east of Beinn nan Gabhar with an altered curvature, and runs across the River Clachaig. Mr. Richey has now traced the dyke as an almost complete ring (Fig. 1).

In several places Mr. Richey has confirmed Mr. Wright's conclusion that the dyke has risen along a fault-fissure marked by crushing. Evidence which was adduced in previous 'Summaries' as suggesting that central subsidence has occurred along the fault, is now differently interpreted. Mr. Bailey, however, supports the suggestion with fresh observations of a displace-

[1] 'The Secondary Rocks of Scotland. Second Paper. On the Ancient Volcanoes of the Highlands, and the Relations of their products to the Mesozoic Strata,' *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 264.
[2] 'Ancient Volcanoes of Great Britain,' 1897, vol. ii, p. 274.
[3] 'Ancient Volcanoes of Great Britain,' 1897, vol. ii, p. 396.

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ment of the outcrops of two inclined sheets of dolerite, or gabbro, crossed by the felsite dyke in Glen Forsa. The sections are not sufficiently well exposed to be conclusive, but the probable downthrow amounts to some hundreds of feet.

That an axis of symmetry exists in Mull was announced by Mr. Wright in the 'Summary for 1910,' p. 38. It runs north-

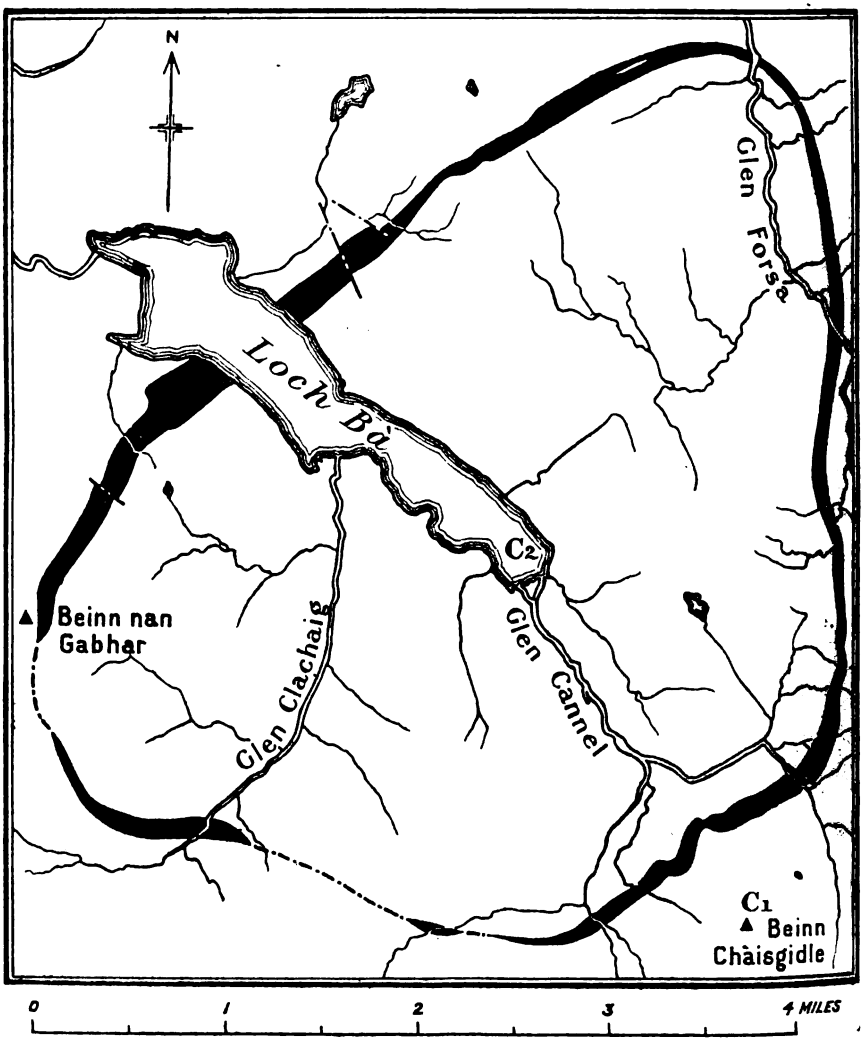

Fig. 2.—Loch Bà Felsitic Ring-Dyke along Fault, Mull.
C_1 and C_2 show two chief centres of ring-dykes and inclined sheets.

west and south-east through Loch Bà, and corresponds with the median line of the Mull swarm of north-west dykes. The mapping of the Loch Bà felsite dyke, as completed by Mr. Richey, furnishes a striking illustration of this symmetry.

(2) Two centres for Ring-Dykes and Inclined Sheets.—In last year's 'Summary,' p. 51, Mr. Bailey, relying

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in part upon earlier results obtained by Mr. Wright ('Summary for 1910,' Fig. 1, p. 33), stated that many of the plutonic masses of Mull "do not behave as inclined sheets, but as great concentric dykes or, as they may be styled conveniently, ring-bosses." Though not plutonic in crystallisation, the Loch Bà felsite is the most perfect example of a ring-boss, or ring-dyke, anywhere known. In most other cases the ring-dykes extend along a limited arc only, and not along a complete circumference. Mr. Bailey and Mr. Richey consider that the distinction between the ring-dykes and the centrally inclined sheets of Mull is natural and essential, but this conclusion is open to criticism since intrusions of the inclined sheet suite, though in the majority of cases centrally inclined at about 45°, and often at lower angles, are also not infrequently steeper, and even vertical.

Mr. Richey has completed the mapping of the ring-dykes of Glen More, previously reported upon by Mr. Bailey, and has proved that they centre about Beinn Chàisgidle, lying outside of the Loch Bà felsite. He has thus demonstrated the existence of two centres of ring-dyke systems, and both centres lie upon Mr. Wright's axis of symmetry (Fig. 1).[1]

For some years past two systems of centrally inclined sheets have been recognised in Mull, an older and a younger respectively. Mr. Wilson, in preparing a small-scale map showing the distribution of the inclined sheets throughout the island, recognised in the spring that the two sets may be ascribed to two distinct centres in much the same positions as the two centres subsequently located by Mr. Richey for the ring-dyke systems.

It is the later set of inclined sheets which corresponds to the north-west centre. The Loch Bà felsite, the latest of the ring-dykes, also belongs to this centre. At the same time the relation of the two centres does not indicate a simple migration of activity from south-east to north-west, for some of the ring-dykes of the south-east centre are later than some of the inclined sheets of the north-west centre. In certain cases, moreover, both centres seem to have been operative in determining the form of an individual ring-dyke.

(3) **Mull Breccia.**—The completion of the field-work in Central Mull has strengthened the view long ago put forward by Professor Judd and Sir A. Geikie that the Mull breccia is essentially an agglomerate. Mr. Bailey in previous 'Summaries' has suggested, although merely as an alternative hypothesis, that the breccia might have resulted from subaerial erosion. The erosion hypothesis is negatived on the following ground:—

(*a*) Increasing difficulty has been experienced in accounting for the *distribution* of the breccia as a product of erosion. Even apart from the restriction of the breccia to Central Mull there are grave obstacles to an attempt to reconstruct a pre-breccia erosion-topography, such as would account satisfactorily for the position of many of the exposures of breccia. The difficulty frequently recurs, but two illustrations must suffice. Thus, for instance, Mr. Anderson states that the river-system which would have to

[1] *Cf.* the two Old Red Sandstone igneous centres, Etive and Glen Coe, situated on the median line of the Etive swarm of dykes. 'The Cauldron Subsidence of Glen Coe and the Associated Igneous Phenomena,' *Quart. Journ. Geol. Soc.*, vol. lxv, 1909, p. 673.

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be postulated south-east of Ben More would correspond too closely with the modern river-system to be at all probable, when the number of post-breccia intrusions of the district is taken into account. The same holds true, according to Mr. Clough, of the Glen More slopes between Cruach Choireadail and Creag na h-Iolaire, where patches of breccia are constantly found in association with older rocks.

(*b*) Important *differences of age* can be established for the breccia in neighbouring outcrops. This result was referred to in last year's 'Summary' (p. 51), where it was pointed out that Mr. Clough had found patches of breccia later than the Corra-bheinn and Ben Buie (Craig) gabbros, whereas the great mass of breccia farther east, previously reported upon by Mr. Bailey, must be regarded as earlier than these gabbros. This difficulty has been shown by further work to be of the first importance. Mr. Wilson finds the gabbro of Ben Buie to be in contact with breccia along both its northern and southern margins; on the north side, west of Loch Airdeglais, the relation corresponds with Mr. Clough's experience, and broken fragments of the gabbro are mingled with the breccia; on the south side the relation is as might be expected from Mr. Bailey's results, and the gabbro is actually chilled against the adjacent breccia. At the same time a careful comparison makes it well nigh certain that the conditions of breccia-formation must have been essentially the same in the two cases. Considering now the depth of cover under which the Ben Buie gabbro must have consolidated, and the very special conditions of erosion which are entailed in the formation of great unstratified masses of breccia, one must admit that the erosion hypothesis is faced in Ben Buie by almost insuperable difficulties. On the other hand these do not affect the alternative hypothesis of recurrent explosions.

Mr. Wilson, in his examination of the region between the River Lussa and Ben Buie, has found fragments of gneiss quite commonly in many exposures of breccia. It may be stated as the experience of those who have been engaged in the mapping of Mull that gneiss fragments abound in the peripheral outcrops of the breccia complex (outside the line drawn for the caldera edge in Fig. 2), but are almost or entirely absent from the more central exposures. The great outcrop of breccia traced by Mr. Wilson between the River Lussa and Loch Airdeglais is seen, near the loch, to be bounded by a vertical junction against the pillow-lava series which now falls to be described.

(4) Pillow-Lavas.—In last year's 'Summary' (pp. 47 and 50) Mr. Clough and Mr. Bailey reported pillow-lavas of Tertiary age from Cruach Choireadail and from Beinn Fhada, between Loch Sguabain and Coire Gorm. Mr. Clough has since found fresh occurrences in the intervening district, while Mr. Wilson has greatly extended our knowledge of the pillow-lavas of Beinn Fhada, and Mr. Bailey has noted additional instances from Beinn Bhearnach and the district to the west, up to the summit of Beinn Talaidh.

The best sections are those mapped by Mr. Wilson in Beinn Fhada. He finds at least three flows in succession showing pillow-structure. The lavas of Beinn Fhada are folded into a gentle syncline along with a thick dolerite sill. In the north-west face of the hill they turn over and dip steeply towards Glen More.

Between Beinn Bhearnach and Beinn Talaidh Mr. Bailey believes that the dip is generally in a south-westerly direction, and finds pillow-structure recurring at intervals through a pile of lavas estimated at not less than 3,000 feet thick. Sediment is rarely found between the successive lavas, but at one place

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50 feet of finely bedded volcanic sandstones and mudstones occur, apparently belonging to the lava series.

The well-marked chilling of the surfaces of individual pillows, and the results obtained by other observers elsewhere, such as Tempest Anderson's observations at Matavanu,[1] have led to the conclusion that the pillow-lavas were formed in water.

Mr. Wilson reports that one of the Beinn Fhada lavas, which shows pillow-structure only occasionally, rests with a well-chilled base upon a thin bed of pumiceous tuff. The chilling recalls the appearance generally met with at the base of a sill, rather than that of a lava, and is ascribable to the good contact between the lava and the soft wet tuff below. This particular lava is 200 feet thick, and sometimes shows pipe-amygdales in its basal portion. Another much more perfect example of pillow-lava is described by Mr. Wilson as showing pipe-amygdales springing from the bases of the individual pillows, and small round amygdales, in concentric zones, at the sides and tops of the same.

(5) History of the Igneous Activity.—The following suggestions in regard to the probable history of igneous activity in eastern Mull are furnished by Mr. Bailey in consideration of certain salient features. The inner limit of the pillow-lava zone, shown in Fig. 2, is largely determined by the occurrence of rocks which may be of later date—including breccias, many intrusions, and a group of very compact andesite lavas. These more central younger rocks may replace or overlie pillow-lavas. The outer limit of the zone is on a different footing. Beyond a belt of ancient gneisses and Mesozoic sediments, with associated Tertiary intrusions, lie the vast lava-fields of Mull and Morvern. As yet pillow-structure is unknown among the lavas of the outer region. This restriction seems to depend upon an original limitation, and not upon the effects of modern erosion, for it is almost certain that in the Coire Mòr syncline (north-east of Beinn Bhearnach) the outer lavas are still to a large extent sheltered beneath breccia supplied from neighbouring necks of a date later than that of the pillow-lavas. It is a fair deduction then that the lake in which the pillow-lavas accumulated was restricted to the centre of Mull. As the lake reappeared at intervals during the development of some thousands of feet of lava, its position was probably determined by a caldera of Hawaiian type, due to subsidence. Furthermore, the small part which sediments play in the infilling of the hollow suggests that the general slope of the surrounding volcanic surface was directed away from the lip of the caldera.

Owing to the wide development of breccia, and other complications, the only place where exposures of the margin of the caldera might be hopefully sought is at the north-east base of Beinn Bhearnach. Here lava occurs on the inside of the line laid down on the map for the caldera edge, and gneiss on the outside. The lava and gneiss have not been found in actual contact, but at two places strips of intensely sheared gabbro intervene—in one case mixed up with a broken remnant of Triassic

[1] *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 631.

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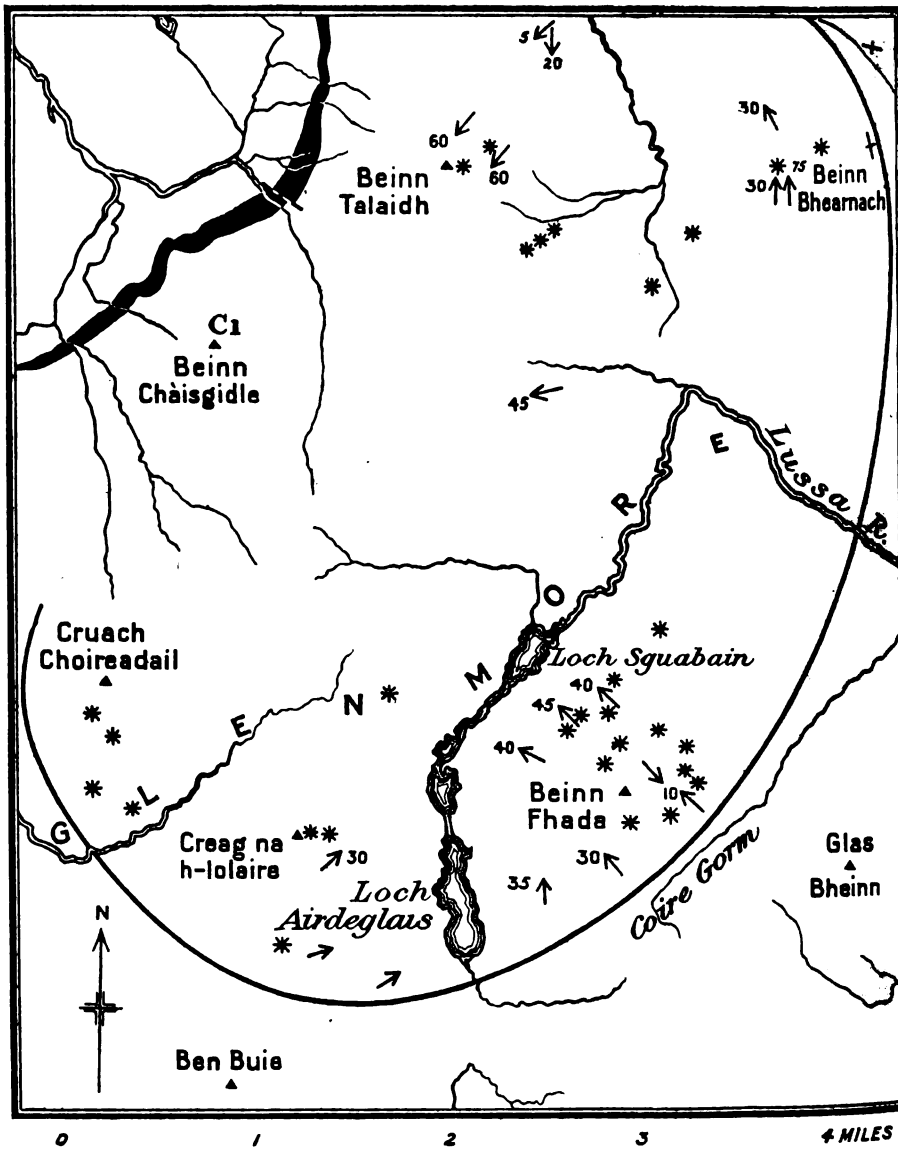

* Exposures of Pillow Lavas.

5↙ Dip, in degrees, of Lavas, Tuffs and Sediments.

✕ Vertical Lavas.

Inferred edge of Caldera, left incomplete owing to lack of evidence.

Loch Bà Ring-Dyke.

FIG. 3.—Distribution of Pillow-Lavas, Mull.

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sandstone. This sandstone is the only representative of the Mesozoic sediments met with on this side of the gneiss outcrop, a fact that in itself carries a suggestion of faulting.

The strong uplift of the zone immediately outside the probable limit of the caldera (*Cf.* Plate, p. 46, in 'Summary for 1912,' and Fig. 5, p. 44, in 'Summary for 1913') may well have been accomplished partly in connection with the intrusion of the Glas Bheinn granophyre. If so, the movement probably continued into the succeeding epoch of explosion which led to the production of a great group of necks roughly corresponding in position with the caldera edge; the components of the breccia of the Coire Mòr syncline indicate a derivation from the necks just mentioned; while the fairly close conformity of the breccia in the syncline with the surrounding lavas ('Summary for 1912,' p. 46) shows that the folding of the latter was probably roughly contemporaneous with their covering up beneath the mass of debris showered upon them.[1] Although the portions of the Glas Bheinn granophyre at present exposed had crystallised completely before the explosive stage was reached, it is possible that it was lower portions of this mass, still unconsolidated, that supplied the vapours. At any rate it was a similar, if not identical, acid magma which exploded, for the breccia contains numerous fragments of rhyolite or felsite not attributable to the surrounding country-rocks, and is also locally accompanied by flows of rhyolite lavas. As a general rule it seems likely that the Mull breccias have resulted from the explosion of acid magma, and in this they differ from the well-known breccia-formation of Iceland.

The preponderance of fragments of country-rock, a very general feature of the Mull breccias, suggests that the explosive vents, though widely developed, rarely settled down to a condition of prolonged activity. The absence of gneiss fragments from the inner zone of breccia outcrops in Mull may be connected with the great depth to which the gneiss floor of the interior appears to have been carried during the formation of the lavas of the caldera, and possibly also of central plutonic masses occupying subterranean cauldrons; outside the caldera, movement of the gneiss floor has locally been in an upward direction.

The production of the older breccias, still preserved on the south flanks of Ben Buie and reaching north-east from Loch Airdeglais, was followed by the intrusion of the greater number of the inclined sheets referable to the south-east centre of Fig. 2. These rocks in turn were succeeded by the great gabbro of Ben Buie, the greater part of which, like the Glas Bheinn granophyre, rose on the outside of the fault bounding the caldera; and after this mass had consolidated, explosions again originated giving rise to the later breccias west and north-west of Loch Airdeglais. To describe the subsequent alternating introduction of ring-dykes and inclined sheets would lead us too far. We need only state that there are very many ring-dykes between Loch Sguabain and Beinn Chàisgidle, and their course is concentric with the line adopted in Fig. 2 as the caldera edge.

[1] *Cf.* Omori's description of the elevation of the New Mountain of Usu San, reviewed in *Geol. Mag.*, 1910, p. 248.

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It is very difficult to determine in many cases whether the ring-dykes of Mull are accompanied by downthrow. It is worth while recalling, therefore, that the arcuate volcanic fissures of Iceland to which Thoroddsen[1] has given so much attention, are sometimes accompanied by internal, and sometimes by external downthrow, but often have no vertical displacement at all.

(2) North and Central Highland District.

L. W. Hinxman, B.A., District Geologist.
R. G. Carruthers,
M. Macgregor, M.A., B.Sc.,
C. H. Dinham, B.A.,
H. H. Read, B.Sc. } Geologists.

Field work has been carried on during the past season in Central Sutherland (Sheets 108 and 102) by Messrs. Macgregor and Dinham, and in Inverness-shire and Perthshire (Sheets 54 and 63) by Messrs. Hinxman, Carruthers, Macgregor and Read.

Central Sutherland.

HIGHLAND METAMORPHIC AND ASSOCIATED IGNEOUS ROCKS.

The area surveyed by Mr. Macgregor between Ben Klibreck and the Crask (Drochaid a' Chraisg) on the Tongue Road is occupied partly by igneous rocks and crystalline gneisses and partly by sediments of Old Red Sandstone age. Among the gneissose rocks a wide range of petrological types is met with; the quartzite of Creag na h-Iolaire, at the north-west end of the Ben Armine ridge, is underlain by a broad zone of pelitic gneiss and granite which forms almost the whole of the high ground round Loch Coire, and on Ben Klibreck is thrown into a series of deep isoclinal folds, inclined to the north-west. Fine sections of this rock are seen at the west end of the Loch Coire hollow: it is here coarsely crystalline, and shows a waved and intermittent foliation. The texture is in the main granitic, and it is often impossible to separate the two elements of which the complex is composed. It is clear, however, that it represents a garnetiferous muscovite-biotite-gneiss which has been thoroughly impregnated with granitic material. Below this belt, and forming the low ground from which rises the Ben Klibreck massif, lies another rock-complex of remarkably diverse aspect. In parts it closely resembles certain types of Lewisian gneiss, and includes banded acid and basic gneisses, red felspathic gneisses and pegmatite veins, while other portions are indistinguishable in the field from siliceous and semi-pelitic rocks of Moine facies. In Coire na Fhearna, on Aileadh Ach'airidh (the Green Face) and at the Allt an Drochardean Beaga bridge on the Tongue road, a transition from an acid granite to one rich in hornblende can be observed, while at each locality the granite has invaded a hornblende-schist. When to this is added a parallel

[1] T. Thoroddsen, 'Die Bruchlinien Islands, und ihre Beziehungen zu den Vulkanen,' *Petermann's Mittheilungen*, Band LI, 1905, p. 49.

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structure in the granite due to flow-movement of the magma during consolidation, a complex rock is produced which bears a strong resemblance to certain Lewisian hornblende-gneisses. The chief interest indeed of the rocks of Central Sutherland lies in the evidence that they afford of the synthetic origin of certain types of gneiss.

The ground examined by Mr. Dinham on the west side of the Lairg-Tongue road is the westward continuation of that mapped by Mr. Macgregor. The greater part of the area is thickly covered by superficial deposits and the few rock exposures consist mainly of massive and flaggy siliceous schists of Moine type. The hornblende-gneisses described in the preceding paragraph extend into the eastern part of this area, but become less frequent to the west and do not cross the Tirry River.

Points of interest are the occurrence of large masses of serpentinised scyelite, possibly *in situ*, east of Loch an Staing, and of a line of boulders of a slightly foliated, pink, felspathic biotite-granite: these follow the north-north-west strike of the surrounding schists and probably indicate the position of a sill below.

A further area mapped by Mr. Dinham to the east and south of Loch Merkland is also occupied by siliceous rocks of Moine type, with occasional pebbly bands; the latter increase in abundance towards the west, where they form the greater part of Ben Hee. On either side of Loch Shin, in the neighbourhood of Overscaig Inn, the schists contain many irregular sills of basic igneous rock. These vary, in their unfoliated condition, from a massive, grey scyelite to a green, porphyritic hornblendite, while the more complete stages of foliation result in the production of unctuous talc-schist. In some of these sills there are clear phenocrysts of a fresh mineral, probably an alkali felspar of secondary origin.

A small amount of acid biotite-gneiss is locally associated with the rocks described above, and on the shore of Loch Shin, one mile south-east of Overscaig, a vein at least 20 feet in thickness, composed of microcline-perthite felspar and quartz, has been traced for $\frac{1}{4}$ mile in a north-west direction. An analysis of this rock has been made by Mr. Radley (see pp. 56, 57).

OLD RED SANDSTONE.

The patch of Old Red Sandstone strata, referred to in a recent report as the most central outlier of that formation in Sutherland,[1] has now been completely mapped by Mr. Macgregor. It extends in a north and south direction for a distance of $3\frac{1}{2}$ miles between Loch Gaineamhach and Meall a' Chnoic, with a breadth of half a mile to a mile. The streams afford good exposures of red and brown sandstones, grits and conglomerates, dipping west at an average angle of 30°. The conglomerates, which form the bulk of the outlier, are made up of angular and sub-angular fragments of gneiss, granite and granite-gneiss, apparently all of local derivation.

[1] 'Summary of Progress for 1912' (*Mem. Geol. Surv.*), 1913, p. 51.

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Inverness-shire and Perthshire.

Highland metamorphic and associated igneous rocks.

The area mapped by Mr. Read in Sheet 63, between Dalwhinnie and the Spey below Laggan Bridge, is almost entirely occupied by an intrusion-complex of granite and siliceous granulites and pelitic schists of the Moine Series.

The complex is especially well displayed on the craggy hills around Loch Caoldair. The granite varies in composition from a highly acid muscovite-granite to a biotite-granite, and in structure from a coarsely pegmatitic to a fine-grained type. The pegmatite does not occur in definite veins traversing the main granite but usually forms rounded or lenticular masses in which the pegmatitic rock is not sharply delimited, and a gradual passage from the coarsest to the finest structure can everywhere be observed.

The more acid type of rock closely resembles, both in structure and composition, the 'Laggan Granite' on the north side of the Spey (Sheet 64).[1]

A characteristic feature of this intrusion is the abundance of inclusions of schist and gneiss which occur in variable quantity throughout the area surveyed. A mile from the margin of the granite these inclusions are in places so numerous as to bulk even larger in the complex than the granite itself. They commonly preserve a constant dip and strike over wide areas, and only in a few instances have they been found to lie at an angle to the general strike of the schists outside the area of intrusion.

No detailed correspondence has yet been found by Mr. Read to hold between the nature of the inclusions and of the granite in which they occur; it is, however, possible to state that in certain areas where the inclusions are of a highly pelitic rock, the granite tends to contain much biotite, in contrast with areas of muscovite-granite where inclusions of siliceous rocks prevail.

The margins of the inclusions are usually sharply defined, and in most cases no assimilation is observable. Good examples, however, can be found of the formation of a granite rich in biotite by the assimilation of a highly pelitic gneiss. The granitic material intruded along the foliation-planes of the gneiss has, in the first stage, incorporated the materials of the latter with the exception of the biotite, which has been left as partings between successive *lits* of granite.

A further stage is reached in the distortion of the dark biotite streaks and their final incorporation into a resulting biotite-granite. A good section showing the incorporation of a biotite-gneiss is exposed in a small road-side quarry at Drumgask, Laggan. The great joint-faces on the south side of Meall na Ceardraich afford fine examples of the bedded appearance produced by rapid intrusion of granitic material along the foliation-planes of a quartz-biotite-granulite which has been completely absorbed, while within a short distance this ***lit par lit*** structure ends abruptly against a mass of unbroken granulite.

[1] 'The Geology of Upper Strathspey,' etc. (Expl. Sheet 64), (*Mem. Geol. Surv.*), 1913, p. 67.

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Dykes and irregular masses of porphyry, definitely intrusive in the granite, are abundant, especially on Ruigh Fhraoich, where they show phenocrysts of quartz, felspar and biotite in a fine-grained base. Dykes of somewhat different type occur on An Dun, Creag na Doire Dubh and in the Allt Mòr.

The high ground on the west side of the Pass of Drumochter, between Loch Garry and Loch Ericht, has been examined by Mr. Hinxman, who finds the prevalent rock to be a flaggy siliceous granulite of the well-known 'Struan Flag' type, with occasional bands of a more pelitic schist. The north-north-east and south-south-west dykes of felsite and porphyry, so abundant in the ground to the south and east, are here only represented by a few minor intrusions. Veins of coarse muscovite-pegmatite and aplite, often several yards in breadth, are, however, abundant—one of these, seen in the stream close to the railway at Balsporran Cottages, is pierced by an epidiorite sill.

The northern extremity of the great through valley of the Pass of Drumochter appears to have been determined by a line of fracture which crosses the shoulder of the Boar of Badenoch and is continued northwards down the valley of the Truim. The storm-gullies, well seen from the railway, that seam the steep eastern face of the Boar, have been eroded in the shattered rock within the crush-zone.

Mr. Carruthers notes, as a point of interest in his further survey of the Ben Alder Forest, along the northern margin of Sheet 54, the unexpected appearance of a sharp synclinal fold of limestone, hornblende-schist and quartzite on the ridge east of Beinn Eibhinn. The close of the fold is clearly seen, the pitch being north-north-east in a direct line with the double limestone and quartzite outcrop at the head of Loch Laggan, with which the Beinn Eibhinn outcrop is no doubt in continuity. These rocks apparently lie above the surrounding Moine schists, and may perhaps represent a further eastward extension of some members of the Lochaber Series; their true relations, however, have yet to be determined.

The belt of 'ermine rock'—a mica schist with large pseudomorphs of biotite after (?) actinolite—previously traced from the Blackwater reservoir to the western shore of Loch Treig, has now been followed from the east side of that loch up to the granite intrusion west of Loch Ghuilbinn. Within the contact zone, for a mile or more, the characteristic pseudomorphs of this curious rock disappear and pale greenish calc-silicate minerals are developed; similar phenomena are seen where the rock approaches the Moor of Rannoch Granite at the west end of the reservoir.

Inverness-shire.

Pleistocene and Recent.

Boulders of the Moor of Rannoch hornblende-granite are abundant on the hill-tops between Loch Garry and Loch Ericht; they strew the shores at the head of the latter and stream north-

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wards over the drift-covered plain between Dalwhinnie and the valley of the Upper Spey. On the hills around Loch Caoldair they become very scarce, indicating the predominance in this region of the ice moving north-eastwards from the high ground of the Ben Alder Forest.

The two deep rock gorges at the head of the Allt an t-Sluic glen, on either side of Creag nan Adhaircean, afford fine examples of overflow channels; through these the drainage from the upper part of the Mashie glen escaped eastwards at a time when the lower part of the valley was blocked by the ice passing northwards through the hollow of Loch Laggan.

The mouths of these gorges debouch on to a conspicuous series of successive alluvial terraces flanking either side of the Allt an t-Sluic valley. Smaller rock-cuts are also seen crossing the ridge of Creag na Doire Dubh and falling eastwards towards Loch Glas-choire.

3.—Ayrshire.

Kilmarnock District.

C. T. Clough, M.A., District Geologist.

E. M. Anderson, M.A., B.Sc.
J. E. Richey, B.A.I.
G. V. Wilson, B.Sc.
} Geologists.

The area revised this year lies mainly in one-inch Sheet 22, but small marginal portions of 21 and 30 have also been examined.

Mr. Richey joined His Majesty's Forces early in the autumn and consequently he did very little surveying in Ayrshire. Mr. Bailey did not assist in Ayrshire, as it was found necessary for him to continue working in the West Highlands through the autumn.

We must express our thanks to many mining companies and proprietors for very valuable assistance.

Calciferous Sandstone Series.

The Hills north-west of Dalry.—Mr. Wilson states that in Kelburn Glen, north of Whatside Hills, the base of the volcanic rocks of Calciferous Sandstone age rests on reddish sandstones of the Upper Old Red Sandstone. In Fairlie Glen, south of Whatside Hills, however, it overlies a few feet of reddish marls which contain cyprids and plant remains,[1] and may possibly be of Calciferous Sandstone age. The lava flows are for the most part of common Lower Carboniferous basic types, both with and without felspar phenocrysts, but several mugearite and more acid flows have been met with. The sequence varies locally, and the mapping tends to show that the series thickens rapidly towards the north, as already stated by Sir A. Geikie.[2]

[1] 'The Geology of North Arran, South Bute, and the Cumbraes, with parts of Ayrshire and Kintyre' (*Mem. Geol. Surv.*), 1903, p. 64.
[2] 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 393.

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CARBONIFEROUS LIMESTONE SERIES.

Kilmarnock.—Interesting sections are still observable in the old limestone quarries near Inchgotrick. About 200 yards south of the farmhouse, Mr. Clough states that the section is somewhat as given below, beginning at the top:—

	ft.	in.
Massive sandstone with abundant garnets. At the base large pebbles of quartz and 'galls' of blaes	20	0
Blaes with lenticular seams of clay ironstone	6	0
Massive dark grey limestone	5	0
Fissile dark grey limestone with abundant remains of *Spirifer*	0	6
Soft blaes	1	0
Clay ironstone seam	0	1
Parroty blaes	0	6
Soft blaes with many nearly horizontal planes of movement	0	6
Clay ironstone seam, with iron pyrites	0	2
Pale grey sandy fireclay	1	0
Cream-coloured compact limestone; fossils not abundant	3	6

The higher limestone is no doubt the band that Mr. Bailey in last year's 'Summary,' p. 64, took provisionally as the top limestone of the Lower Limestone Division; and the massive sandstone above it is part of the division which was called the middle Coal-bearing Division. It may be remembered that the thickness attributed to this last division was only 40–50 feet. In the Inchgotrick quarries the top of the sandstone is not seen, and we are not at present in a position to make an estimate of the total thickness of the middle Coal-bearing Division in that locality. But it is important to notice that an examination of the Inchgotrick sections discloses the existence of various important planes of movement, some of which run so nearly along the bedding that they might readily escape observation: also, that between two of these planes we see in one place about 50 feet of beds, chiefly consisting of sandstone, fakes and blaes, which are not visible anywhere else in the quarries. These beds come in between a plane of movement which runs along the base of the top massive sandstone, and another rather lower plane which varies in inclination from place to place, but ultimately coalesces with or comes very near the upper plane. It seems probable, then, that at Inchgotrick the original thickness of the middle Coal-bearing Division is not 40-50 feet, but at least twice as much. It is very possible that besides the 50 feet of sandstone, fakes and blaes already noticed, other beds were originally present, but have been cut out near almost horizontal planes of movement. That the planes spoken of as planes of movement are really so, can be satisfactorily made out by a variety of considerations, among which we may specially mention, (1) the presence of a very thin crush-clay along some of the planes. (2) the severe contortions accompanied with over-folding found in one place at the base of the massive sandstone, along which the main plane of movement seems to occur, (3) the sharp truncation by one nearly horizontal plane of steep strata just above it, (4) the existence, below the massive sandstone, of a series

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of more steeply inclined fault planes, with normal but small throws, which end at the base of the sandstone.[1]

About 200 yards slightly west of south of Inchgotrick a nearly east-and-west dyke of white trap, about 18 inches wide, cuts distinctly through the lower part of the section, but is not seen in the massive sandstone. About 8 yards to the north, a thin dyke, also nearly east-and-west, cuts through the massive sandstone, but is not distinct in the lower part of the section. Hence at first the impression was acquired that the two intrusions referred to might be two parts, an upper and a lower, of one dyke that had been broken through and displaced along a plane of nearly horizontal movement running at the base of the sandstone. Closer examination, however, showed that the dyke on the south comes to an end as it goes upwards a little before it reaches the base of the sandstone, and, also, that the dyke on the north is in reality continuous from top to bottom of the section, though it is not distinct in the lower part. It is clear, therefore, that two parallel dykes are present here, and that the northern one has been injected since the formation of the plane of movement referred to.

It may be added that the base of the sandstone contains, in addition to the clastic ingredients already mentioned, a considerable proportion of iron pyrites, and some specks of galena. Both these minerals are of secondary origin, and may perhaps have been introduced by solutions proceeding along the plane of movement immediately below.

The missing out of beds near such nearly horizontal planes of movement should be borne in mind when considering possible explanations of the unusually poor development of the Carboniferous Limestone Series near Inchgotrick and for some miles to the east. This poor development has long been known.[2] To further emphasise it, Mr. Bailey's estimate of 85-105 feet in last year's 'Summary,' p. 64, may be compared with the section of more than 100 fathoms, found in Bore No. 12, Caprington,[3] the site of which is less than a mile slightly west of north of Inchgotrick.

MILLSTONE GRIT—COAL MEASURES.

Reference was made in last year's 'Summary' (p. 65) to a hard buff clay immediately overlying the Millstone Grit lavas. A hard clay seems invariably to occur in this position, and it is always speckled with iron carbonate, while in places it contains plant remains. It may attain 12 or 13 feet in thickness. A good section was observed by Mr. Anderson in the Annick Water just below Cunninghamhead Mill. Here Millstone Grit lavas

[1] Reference may be made to a section in the Auchinback railway cutting described in the 'Geology of the Glasgow District' (*Mem. Geol. Surv.*), 1911, p. 171, where a small fault truncates the Index Limestone, and terminates abruptly at the base of the overlying Barrhead Grit. Similar phenomena have been observed in many other localities.

[2] Sir A. Geikie. 'Explanation of Sheet 22' (*Mem. Geol. Surv.*), 1872, p. 20.

[3] An abbreviated journal of part of this bore is given by Mr. Dron in 'The Coal-Fields of Scotland,' 1902, p. 47.

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are seen to pass upwards into a white argillaceous rock which is still vesicular. This is overlain by a hard white clay which is distinctly laminar, and has evidently been formed by re-arrangement from the rock underneath.

INTRUSIVE IGNEOUS ROCKS.

The Hills north-west of Dalry.—Near Baidlandhill Farm two volcanic necks have been noted by Mr. Wilson, both of which are intruded through the lavas. One that forms Baidland Hill consists of a dirty green ash, weathering spheroidally, and contains many fragments of sandstone and lava. The other is situated just behind the farm mentioned above, and is well exposed in a cross section in the burn north of the house.

The material consists for the most part of a fine black ash, weathering spheroidally, and contains fragments of charred wood and occasional olivine nodules, but the outer western portion in this burn includes many derived sandstone slabs, and shows a steep dip of about 60° towards the centre of the vent. A coal is said to have been worked just behind the farm, and may perhaps belong to a mass let down into the vent.

Another small vent is seen breaking through the beds just below the Highfield Limestone at the bend of the Caaf Water near Holmbyre. The material is a dark brown ash containing rounded flat lumps of biotite. Mr. A. F. Macconochie has searched it closely and found several marine fossils, *Productus latissimus*, *Euphemus urei* and *Orthoceras*, embedded in an ashy matrix. It seems, therefore, probable that this represents a submarine volcano in activity in Lower Carboniferous times.

Kilmaurs.—A remarkable case of curved jointing was observed by Mr. Anderson in an intrusive dolerite wrought at Rashillhouse Quarry, north of the farmhouse of that name. Here the joints form in section, roughly speaking, a series of confocal ellipses; the outermost are seen at one point to be parallel to the margin of the intrusion.

Kilmarnock.—The workings of No. 3 Pit Craig (Messrs. Wm. Baird & Co., Ltd.) show two veins of volcanic ash which 'burn' the adjacent coal, and appear to coalesce in an easterly direction. These veins are of much interest because they are very narrow in proportion to their length, and also show curved and rapidly varying directions. So far as yet disclosed, the longer band extends for at least 360 yards, though the average breadth is only 10–20 yards.[1] The parts of both veins are in places almost semicircular, but the general directions are perhaps not far from east-and-west.

Sections in the underground roads examined by Mr. Clough show that the sides of the veins are sometimes of very irregular form: occasionally a side runs almost horizontally and overlies

[1] For figures and descriptions of other greatly elongated masses of ash reference may be made to Sir A. Geikie's 'Ancient Volcanoes of Great Britain,' 1897, vol. i, p. 53: also to descriptions by Dr. Peach and Mr. Symes in 'The Geology of the Country near Oban and Dalmally.' (*Mem. Geol. Surv.*), 1908, pp. 135-138.

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adjacent strata for a yard or two, as if it were the base of a bedded contemporaneous ash, but, a little distance farther on, the same side twists sharply and underlies the same strata. The impression is conveyed that the ash has been formed under the influence of great pressure, and that it has sometimes been forced along the bedding, even though on the average the sides are perhaps nearly vertical. It is to be noted, too, that in spite of the occasional penetration along the bedding, the adjacent strata are not specially disturbed, and that the Parrot Seam (Splint of Annandale Colliery) lies at the same level at either side of the longer vein.

Among the fragments in the ash are angular pieces of blaes, sandstone and ironstone, as well as vesicular decomposed white trap. Some of the sandstone slabs are as much as 3 feet in length. A similar ash is exposed on the south bank of the River Irvine, near Cockhill, and is known farther east also in the workings of No. 3 Pit, Fairlie, (Caprington and Auchlochan Coal Co., Ltd.). It seems quite possible that the ash forms a continuous vein from No. 3 Pit, Craig, to the last-mentioned workings, a distance of nearly three-quarters of a mile.

GLACIAL DEPOSITS.

Mr. Anderson noticed that east-and-west drumlins are well developed between Cunninghamhead and Kilmaurs. South of Kilmaurs a distinct set of smaller drumlins have the direction N. 30° E. The latter appear in some cases to modify pre-existing drumlins of the east-and-west type. The presence of N.N.E. or N.E. drumlins in the country around Kilmarnock has been noted by Mr. Clough,[1] and near Dundonald certain crags of dolerite have distinct 'tails' to the south-west. One is led to conclude that there were two periods of glaciation in this part of Ayrshire; a period in which the motion was either from east to west or from west to east, and a probably later period in which the ice came from the north-east.

ECONOMICS.

Shewalton Peat Moss is at present being rather extensively wrought by the Ayrshire Moss Litter Company. Mr. Anderson is informed that the material is used to form litter for horses and bedding for poultry. A certain portion is granulated and mixed with treacle to serve as a fodder for cattle. For these purposes a soft, little altered peat is required, as opposed to the more solid variety which is preferred for burning.

4.—Renfrewshire and South Lanarkshire District.

L. W. Hinxman, B.A., District Geologist.
R. G. Carruthers.
M. Macgregor, M.A., B.Sc. } Geologists.
C. H. Dinham, B.A.

[1] 'Summary of Progress for 1912' (*Mem. Geol. Surv.*), 1913, p. 58.

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The examination of the Carboniferous areas in the Johnstone district (Sheet 30), included in the Lanarkshire basin, has now been completed by Mr. Carruthers, and the resurvey of the Hamilton and Larkhall coalfields (Sheet 23) by Messrs. Macgregor and Dinham. Revision work has also been continued by Mr. Macgregor in the Morningside coalfield and by Mr. Hinxman in the country around Lanark.

Lanark District.

CALCIFEROUS AND OLD RED SANDSTONES.

In the area to the north-east of Lanark, revised by Mr. Hinxman, a cake of Calciferous Sandstone strata of variable thickness rests unconformably upon the uneven surface of the Lower Old Red Sandstone. The gorge of the Mouse Water, between Cleghorn Mill and Jerviswood, has been eroded down through this cake to the underlying Old Red Sandstone, and at several points along its course the discordance between the green and yellow sandstones and variegated marls of the younger, and the purple micaceous sandstones of the older formation is well displayed.

The valley of the Clyde, above and below Hyndford Bridge, is occupied by a belt of reddish and white calcareous sandstones with bands of nodular cornstone. In the original survey these rocks were grouped as a lower division of the Calciferous Sandstone Series. From their lithological character they are now regarded as of Upper Old Red Sandstone age.

The amount of overlap is indicated by the occurrence of the Upper Old Red cornstones within half a mile of the outcrop of the quartzite-conglomerate on the Chapel Hill, three miles south of Hyndford Bridge. As this conglomerate is regarded as a member of the Downtonian Series, the Upper Old Red Sandstone in this region appears to have transgressed nearly the whole of the strata of the Lower Division of that formation.

COAL MEASURES.

Hamilton.—The revision of the Hamilton coalfield has now been completed by Mr. Macgregor. During the interval of more than 40 years that has elapsed since the original survey of the district, Hamilton has been the centre of a very active mining industry, but the coals are now rapidly approaching exhaustion, and within recent years some half-dozen collieries have ceased working. The seams still wrought in this field are the Ell, Pyotshaw, Main, Humph, Splint, Blackband, Virtuewell and Kiltongue. Of these the Ell, Main and Splint are all but worked out, although valuable reserve areas still exist under the town itself.

The Ell Coal averages 7 feet 4 inches in thickness, including 2 feet of inferior 'head' coal and 5 feet 4 inches of 'breast' coal. The Main varies from 4 feet to 4 feet 8 inches, and the Splint from 4 feet 4 inches to 5 feet 8 inches, both seams

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containing bands of splint coal. The Virgin is 1 foot 2 inches thick, and lies from one to seventeen inches below the Splint; at Barncluith it reaches 1 foot 9 inches, and at Udston 3 feet, the Splint being reduced at these localities respectively to 4 feet 2 inches and 3 feet 8½ inches.

Mining is at present chiefly confined to the Pyotshaw, Humph, Blackband and Kiltongue seams. The Pyotshaw averages 3 feet 2 inches at Cadzow and Barncluith and reaches 3 feet 7 inches at Earnock, 4 feet 2 inches at Udston, and 4 feet 3 inches at Bent. The Humph is generally 3 feet thick, the Blackband Coal 2 feet 2 inches; at Cadzow Collieries the latter is of inferior quality, and appears to represent a transition stage between the Blackband Ironstone of Quarter and the Blackband Coal of Bent, Udston and Earnock. The Virtuewell is poorly developed in this field, and rarely exceeds 1 foot 6 inches. The Kiltongue reaches 2 feet 5 inches at Cadzow and 2 feet 9 inches at Bent, but elsewhere is only from 1 foot 6 inches to 1 foot 8 inches in thickness.

Larkhall and Quarter—The northern part of this district, revised by Mr. Dinham, adjoins the Hamilton field, and the preceding remarks apply also to this area. In addition to the coal seams mentioned above, the Lower Drumgray is wrought in the Bog and Home Farm Collieries, where it has an average thickness of 2 feet 5 inches. In the Quarter district the 'Musselband' of Crookedstone and Wellbog has been identified with the 'Upper Slatyband Ironstone' formerly mined on a small scale at Cherry Hill, near Larkhall. The 'Slatyband' of Crookedstone corresponds to the 'Lower Slatyband Ironstone' once wrought at Glenavon and near the Stonehouse viaduct.

Morningside.—Revision work was also carried on by Mr. Macgregor in the Morningside district, along the eastern edge of the Wishaw coalfield, where the lowest workable seam is the Mill Coal. Areas of burnt coal are met with in the workings of the Kiltongue and Lower Drumgray seams in this area.

Renfrewshire.

Pleistocene and Recent.

In the area north of Johnstone, Mr. Carruthers finds that the 100-ft. beach persists normally at least as far to the west as Bishopton, so that south of the Clyde there is no break in this line comparable with that previously observed on the north side of the river.[1]

III.—PETROGRAPHICAL WORK.

(1.) England and Wales.

Most of the petrographical work has been in connection with the surveying now in progress in North Wales and the Midlands. The petrographer has also contributed accounts of the igneous rocks for the forthcoming memoir on Sheet 227 of the one-inch map.

[1] 'Geology of the Glasgow District' (*Mem. Geol. Surv.*), 1911, p. 191.

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A report has been drawn up on the micro-structure and mineral-contents of a number of building stones which are undergoing weathering and other tests at the Museum of Practical Geology.

A mineral associated with the pillow-lavas of Anglesey, collected by Mr. Greenly, has proved to be axinite. Hitherto this mineral has not been detected in Britain in such large masses outside Devon and Cornwall.

Dr. Thomas has completed his investigations into the character of the igneous rocks from the deep-boring in the Island of Bermuda, and in addition to the mellilite-basalt mentioned last year he has detected a suite of analcite-bearing rocks which may be classed with the lamprophyres and monchiquites. Many of the types find their parallel in the fourchite and ouchitite of Williams and Kemp. His report has been incorporated with that of Dr. L. V. Pirsson, of Yale University, and published in the American Journal of Science (vol. xxxviii., p. 331).

A large number of British rocks has been studied at the instigation of the Road Board, but they present no special features of petrographical interest.

Mr. T. C. Hall, of the Camborne School of Metalliferous Mining, in continuing his detailed survey of Lundy Island, the results of which he has proposed to offer to the Geological Survey, has met with a type of dyke-rock which appears to be new to science, and to which he intends to apply the name 'lundyite.' The rock occurs in two phases, an orthophyric phase and a glassy phase. Both rocks are rich in alkalis, and the more crystalline variety is peculiar in containing a katophoritic amphibole. Two analyses of these rocks have been made and are given on p. 56.

(2.) Scotland.

The greater part of the work carried on in the London office has been in connection with the complex Tertiary igneous rocks of the Island of Mull, and the older volcanic and intrusive rocks of the Ayrshire Coalfield and adjacent districts. Most of it has been incorporated in the field-descriptions given on previous pages. Attention may be drawn to a remarkably perfect example of pillow-lavas.

Xenolithic rocks similar to those of the Nun's Pass, near Carsaig, have been detected at many fresh localities. The igneous rocks that carry the xenoliths appear to be similar in all cases, and to be referable to a variety of the leidleites. (*See* Analysis, No. 432, p. 57.) The xenoliths are derived from several distinct types of rock, including highly aluminous shale, sandstone, and basic igneous rocks. The aluminous shales have been converted into sillimanite-hornfels (*see* analysis, No. 431, p. 57), and sapphire and spinel-bearing rocks, similar in all respects to those mentioned in last year's 'Summary.' In addition, however, Dr. Thomas has under investigation a number of most beautiful cordierite-bearing xenoliths which contain pink

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spinel and other interesting minerals. Some of these cordierite-rocks contain relatively large crystals of rose-pink sillimanite which range up to one centimetre in length.

During the course of the petrographical work on the minor intrusions of Mull it has been found necessary to distinguish certain widely distributed rock-types. The name 'Inninmorite' is applied to a moderately basic glassy rock containing small crystals of labradorite and of a non-aluminous iron-magnesian augite which is optically uniaxial or nearly so. An analysis of this augite was given in last year's Summary. Under the name 'Leidleite' is distinguished a group of intrusive rocks which present affinities with the tholeiites, but differ in certain essentials. They consist of plagioclase felspar, aluminous augite and magnetite in a glassy or devitrified base. An account of these rocks, with full definition of the types, has been presented recently to the Geological Society of London.

Mr. McLintock has continued his work on the metamorphosed lavas of An Gearna, Mull; he has separated, and caused to be analysed (No. 416, p. 55), an interesting pale-yellow calcium-aluminium garnet from these rocks.

IV.—CHEMICAL WORK.

During the year 1914 ten complete analyses were made, seven of these related to matters of scientific interest in igneous rocks, two being in connection with the work now in progress on the sapphire-bearing rocks of Mull. In addition an analysis was made to determine the value of a vein of pegmatite as a source of potash, and another to find the percentage of available alumina in a supposed bauxite.

A garnet, rich in lime and alumina, which had been separated by Mr. McLintock from a rock occurring in the Isle of Mull, was also analysed.

During this year also the work in connection with a series of six building-stones now undergoing tests on their resistance to weathering was completed. It involved complete analysis, and estimations of the porosity, specific gravity, and resistance to frost of all six stones.

A series of 46 coals was analysed in the Government Laboratory for inclusion in the new edition of the memoir on 'The Coals of South Wales.'

16809. Lab. No. 411. *Tholeiite of Brunton type.* Three-foot dyke. Shore ¼ mile N. of Kintallen, 3 miles N.N.W. of Salen, Mull, Sheet 44. Structure intersertal. The rock consists of augite, moderately basic plagioclase, magnetite and dark interstitial glass.

16800. Lab. No. 412. Craignure type[1] of inclined Tertiary sheet. Allt an Dubh-choire, 3,650 feet from junction with Scallastle River, Mull, Sheet 44.

16802. Lab. No. 413. Craignure type[1] of inclined Tertiary sheet. Allt an Dubh-choire, 1,900 feet from junction with Scallastle River, Mull, Sheet 44.

[1] *See also* Analysis No. 394, 'Summary of Progress' for 1913, p. 80.

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Slice No. ...	16809.	16800.	16802.
Lab. No. ...	411.	412.	413.
SiO_2	51·63	55·82	66·27
TiO_2	2·00	1·62	·87
Al_2O_3	11·77	11·47	11·92
Fe_2O_3	3·23	3·68	3·09
FeO	10·47	7·66	3·18
MnO	·35	·40	·31
(CoNi) O	·04	·04	nt. fd.
BaO	·03	·03	nt. fd.
CaO	9·34	7·88	3·30
MgO	5·02	4·08	1·44
K_2O	·91	2·00	4·03
Na_2O	2·90	2·55	2·89
Li_2O	nt. fd.	trace	trace
H_2O at 105° C.	·68	·66	·78
H_2O above „	1·40	1·88	1·51
P_2O_5	·29	·23	·17
FeS_2	·08	·09	nt. fd.
CO_2	·11	·08	·53
Total ...	100·27	100·18	100·29

ANAL. E. G. RADLEY.

Garnet, pale yellow, in Tertiary lavas metamorphosed by intruded granophyre. North-east slope of An Gearna, I. of Mull, Sheet 44, Scot. Lab. No. 416.

SiO_2	37·66
TiO_2	·12
Al_2O_3	21·84
Fe_2O_3	4·07
FeO	·34
MnO	·53
(CoNi)O	nt. fd.
CaO	33·06
MgO	·45
K_2O	·75
Na_2O	1·17
Li_2O	nt. fd.
H_2O at 105°C	nt. fd.
H_2O above „	·20
Total	100·19

Sp. Gr. 3·61 at 7°C.

ANAL. E. G. RADLEY.

Lab. No. 421. An impure ironstone about 8 ins. thick and immediately below the 8-inch coal. From a short adit near top of W. side of Fenwick Water, about 1,200 feet E.S.E. of Southcraig. 1 inch map, 22 Scot. Ayr 18, N.W.ª.

Lab. No. 422. An impure ironstone about 8 inches thick and from 8 inches to 16 inches below an 8-inch coal. From a short adit near the top of W. side of Fenwick Water, about 1,200 feet E.S.E. of Southcraig. 1-inch map, 22 Scot. Ayr 18, N.W.ª.

Lab. No. 423. An impure ironstone about 8 inches thick, and immediately above an 8-inch coal. From a short adit near the top of W.

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side of Fenwick Water, about 1,200 feet E.S.E. of Southcraig. 1-inch map, 22 Scot. Ayr 18, N.W.ᴮ.

	Lab. No. 421.	*Lab. No.* 422.	*Lab. No.* 423.
Fe_2O_3	2·01	2·30	1·57

All iron estimated as Fe_2O_3 owing to the presence of carbon.

ANAL. E. G. RADLEY.

S. 17507. Lab. No. 424. A greatly decomposed lava-flow belonging to the Millstone grit series, probably an *olivine dolerite* originally. One quarter of a mile N. of Borland (House). Greenish, clay-like band, perhaps 20 feet above the level of Fenwick Water on its western side. Sheet 22.

E. 9232. Lab. No. 428. *Lundyite.* Orthophyric phase. Dyke, 20 feet broad in small cove, 240 yards N.N.W. of landing-place, Lundy Island. Sheet 291.

E. 9213. Lab. No. 429. *Lundyite.* Spherulitic pitchstone phase. From dyke where it thins out and becomes glassy. W. side of small cove, W. side of Mermaid's Hole, Lundy Island.

Slice No. ...	17507.	E9232.	E9213.
Lab. No. ...	424.	428.	429.
SiO_2 ...	30·09	67·43	62·83
TiO_2 ...	3·47	·36	·36
Al_2O_3 ...	22·90*	14·13	13·54
Fe_2O_3 ...	4·84	1·31	·95
FeO ...	19·37	2·94	3·12
MnO ...	·15	·32	·38
(CoNi)O ...	nt. fd.	nt. fd.	nt. fd.
BaO ...	nt. fd.	nt. fd.	·24
CaO ..	1·01	1·18	1·12
MgO ...	2·10	·30	·33
K_2O ...	·50	4·96	7·12
Na_2O ...	·31	5·14	3·44
Li_2O ...	trace.	nt. fd.	trace.
H_2O at 105° C. ...	3·64	·33	2·17
H_2O above „ ...	10·40	·77	4·34
P_2O_5 ...	·55	·32	·43
FeS_2 ...	nt. fd.	nt. fd.	nt. fd.
CO_2 ...	·94	·84	·03
Total ...	100·27	100·33	100·40

* Of the Al_2O_3 found 14·80 per cent. was in an 'available' form.

ANAL. E. G. RADLEY.

Lab. No. 431. Xenolith from basic sill. Nun's Pass, Carsaig, Mull. Sheet 44. The rock is a *Sillimanite-hornfels*, and consists entirely of minute slender needles of sillimanite set in a colourless glassy base. The sillimanite in the thicker prisms has a pale pink colour.

S. 17170. Lab. No. 432. Allied to *Leidleite.* Basic portion of composite intrusion, which carries sapphire-bearing xenoliths. Rudh a chromain, W. side of Carsaig Bay, Mull, Sheet 44. The rock is of moderately fine grain, and consists of granules and prisms of augite, irregular laths of zoned labradorite, magnetite, and a fair quantity of free quartz.

S. 18173. Lab. No. 434. Coarse *Pegmatite.* Shore of Loch Shin, S.E. of Overscaig Inn, Sutherlandshire. Sheet 108.

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Slice No. ...		17170.	18173.
Lab. No. ...	431	432.	434.
SiO_2	49·74	53·97	72·94
TiO_2	1·49	1·24	·06
Al_2O_3	34·99*	14·65	14·26
Fe_2O_3	1·53	3·62	·21
FeO	·34	6·32	·22
MnO	·15	·30	·11
(CoNi)O	nt. fd.	nt. fd.	nt. fd.
BaO	nt. fd.	·04	·25
CaO	·88	7·98	·23
MgO	·66	4·49	·08
K_2O	1·72	1·52	7·42
Na_2O	3·76	2·54	3·49
Li_2O	trace.	trace.	trace.
H_2O at 105° C.	·61	1·92	·05
H_2O above „	3·44	·94	·17
P_2O_5	·86	·27	·49
FeS_2	nt. fd.	·09	nt. fd.
CO_2	·04	·51	·96
Total ...	100·21	100·40	100·04
Sp. Gr.	2·65 at 7°C	2·83 at 7°C	—

* Of this ·48 per cent. is present as corundum.

ANAL. E. G. RADLEY.

V.—PALÆONTOLOGICAL WORK.

(1.)—ENGLAND AND WALES.

No points of special scientific interest have arisen during the year from a study of the palæontological materials collected in the course of the current Survey work. Mr. Allen and Mr. Pringle have determined large series of specimens of various age, from Ordovician to Post-Tertiary, inclusive. The results will be incorporated in the respective sheet-memoirs. Special collections made from the Cambrian, Ordovician and Silurian rocks of Shropshire, under the guidance of Professor Charles Lapworth, are at present being studied by Professor Lapworth.

Series of bones from Kent's Cavern and from the Cresswell Crags, formerly part of the collection of the Geological Society, have been named and placed in the Museum by Mr. Allen, who has also completed the revision of the Cretaceous Lamellibranchs exhibited in the Museum and the preparation of a catalogue of the types and figured specimens among them (see Appendix II., p. 66).

An important instalment of a monograph on the British Carboniferous *Producti*, by Dr. Ivor Thomas, has been published in quarto form. This work deals with the pustulose and fimbriate species and includes also comprehensive chapters introductory to the study of all the Carboniferous *Producti* of Britain.

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A specimen of Cirripede in the Museum, obtained many years ago from the Upper Chalk of Watford Tunnel, has been shown by Mr. T. H. Withers to have a high interest. Mr. Withers finds that this form constitutes a link between the stalked Cirripedes of the family Pollicipedidæ and the sessile a symmetrical Cirripedes of the family Verrucidæ. He makes this specimen the type of a new genus and species, *Proverruca vinculum*.[1]

The following specimens in the Museum have been figured and described during the year:—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1913. (Published 1914.)

The Pliocene Mollusca, Part I.

By MR. F. W. HARMER, F.G.S., F.R.M.S.

Terebra inversa *Nyst*, pl. ii. fig. 6, p. 55.
,, ,, *var.* costata *Harmer*, pl. ii, fig. 7, p. 54.
Buccinum meridionale *Harmer*, pl. ix, fig. 1, p. 111.
,, ,, *var.* inflata *Harmer*, pl. ix, fig. 3, p. 112.
,, totteni *Stimpson*, pl. x, fig. 8, p. 114.
Murex rudis *Borson*, pl. xii, figs. 3, 5, p. 122.
Ocinebra tortuosa, *var.* minor *Harmer*, pl. xii, fig. 9, p. 125.
,, erinacea (*Linn.*), pl. xii, fig. 13, p. 124.
Trophon lamplughi *Harmer*, pl. xii, fig. 22, p. 134.
,, fabricii *Moeller*, pl. xii, fig 27, p. 130.
,, ,, *var.* bailyi *A. Bell*, pl. xii, fig. 29, p. 131.
Searlesia costifer, *var.* monensis *Harmer*, pl. xiii, fig. 6, p. 140.
Nassa woodwardi *Harmer*, pl. xiii, fig. 18, p. 83.
Searlesia forbesi *Harmer*, pl. xiv, figs. 1, 2, p. 140.
,, nordmanni *Harmer*, pl. xiv, fig. 4, p. 146.
,, björnsoni (*Mörch*), pl. xiv, fig. 8, p. 141.
,, lundgreni (*Mörch*), pl. xiv, fig. 12, p. 143.
,, φyeni *Harmer*, pl. xiv, figs. 19, 20, p. 143.
,, harrisoni *Harmer*, pl. xiv, fig. 21, p. 144.
Fusus longiroster (*Brocchi*), pl. xiv, fig. 23, p. 173.
,, lamellosus *Borson*, pl. xiv, fig. 24, p. 174.
Sipho sarsi (*Jeffreys*), pl. xxii, fig. 12, p. 198.
,, menapiae (*A. Bell*), pl. xxiii, figs. 17, 18, p. 186.

British Graptolites. Part X.

By MISS G. L. ELLES, SC.D. AND MISS E. M. WOOD, D.Sc.

Monograptus (Rastrites) longispinus (*Perner*), pl. 1, fig. 2g, text-fig. 344b, p. 489.
,, (,,) setiger *Elles and Wood*, pl. 1, figs. 3a, d, text-fig. 345, p. 490.
,, (,,) hybridus (*Lapworth*), pl. 1, fig. 4c, text-figs. 346a, b, p. 491.
,, (,,) approximatus, *var.* geinitzi (*Törnquist*), pl. 1, figs. 5a–e, text-figs. 347a, b, p. 492.
Cyrtograptus hamatus (*Baily*), pl. lii, fig. 3, text-fig. 356, p. 510.

IN THE GEOLOGICAL MAGAZINE, Vol. I., 1914.

The Foraminifera of the Speeton Clay of Yorkshire.

By DR. R. L. SHERLOCK, A.R.C.S.

Cristellaria chapmani *Sherl.*, pl. xix, fig. 7, p. 261.
Lagena apiculata, *var.* danfordi *Sherl.*, pl. xviii, fig. 8, p. 256.
Pulvinulina lamplughi *Sherl.*, pl. xix, fig. 16, p. 290.

[1] T. H. Withers. 'A remarkable new Cirripede from the Chalk of Surrey and Hertfordshire,' *Proc. Zool. Soc. Lond.*, 1914, p. 945.

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In the Proceedings of the Zoological Society of London, December, 1914.

By Mr. T. H. Withers, F.G.S.

Proverruca vinculum *Withers*, text-figs. 1c–f, p. 947.

In the British Museum Catalogue of the British Species of Pisidium.

By Mr. B. B. Woodward, F.L.S.

Pisidium casertanum (*Poli*), pl. xiv, figs. 1a, b; pl. xviii, figs. 5a–f, p. 31.
,, lilljeborgi *Clessin*, pl. xxviii, figs. 20a-d, 24a–d, p. 111.
,, milium *Held*, pl. xxix, figs. 10a, b, 30a–f, p. 70.

In the Memoirs of the Geological Survey (Palæontology), Vol. I., Part 4.

By Dr. Ivor Thomas.

Pustula elegans (*M'Coy*), pl. xvii, figs. 1, 2, 4, p. 292.
,, venusta *Thom.*, pl. xvii, fig. 6, p. 297.
,, exquisita *Thom.*, pl. xvii, figs. 7, 8, p. 302.
,, subelegans *Thom.*, pl. xvii., figs. 9, 11, p. 298.
,, eximia *Thom.*, pl. xvii, figs. 13, 15, p. 301.
,, punctata (*Mart.*), pl. xvii, figs. 17–19, p. 303.
,, pustulosa (*Phill.*), pl. xvii, figs. 24–28; pl. xviii, fig. i, p. 261.
,, ovalis (*Phill.*), pl. xviii, fig. 2, p. 267.
,, pyxidiformis (*de Kon.*), pl. xviii, figs. 5, 6, p. 269.
,, rugata (*Phill.*), pl. xviii., figs. 10, 11, p. 281.
,, nodosa *Thom.*, pl. xix, figs. 1, 2, p. 287.
,, interrupta *Thom.*, pl. xix, fig. 3; pl. xx, fig. 5, p. 273.
,, distorta *Thom.*, pl. xix, figs. 4–6, p. 290.
,, carringtoniana (*Dav.*), pl. xix, fig. 14, p. 324.
,, magnituberculata *Thom*, pl. xix, fig. 15, p. 277.
,, tenuipustulosa *Thom.*, pl. xx, figs. 10, 11, p. 288.
Overtonia fimbriata (*J. de C. Sow.*), pl. xx, figs. 13, 14, 16, 17, p. 335.

In the Linnean Society, Journal of the Proceedings:

Botany, Vol. LII.

By Mr. and Mrs. Clement Reid.

Corema intermedia *C. and E. M. Reid*, pl. 531, p. 113.

In 'Country Life,' Vol. XXXVI.

By Sir E. Ray Lankester, K.C.B., F.R.S.

'Cassidaria,' No. 938, Dec. 26th, text-fig. 3, p. 844.

(2.) Scotland.

During the year 3,754 fossils were obtained. They are from the Carboniferous areas being now revised in Ayrshire and Lanarkshire, and also from boring operations in various parts of the country. The special collection of Mesozoic fossils begun last year in Raasay, was continued in the adjacent districts of Applecross and Skye. Mr. Tait also obtained a suite of Tertiary plants from the well-known Ardtun leaf-bed in Mull, which will be submitted to a specialist as soon as opportunity arises.

There is nothing new to report in connection with the materials from the Carboniferous areas.

The Jurassic brachiopods and ammonites of Applecross and Skye are now in the hands of Mr. Buckman. Since his final

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report is not yet ready the detailed account of the palæontological sequence of the district must be deferred. Still, his preliminary examination of the materials is of great interest, and of this a short digest is given below in order to show the main outlines of the results achieved.

A detailed examination of the sequence in the Applecross district shows that the rocks mapped during the original survey as Rhætic belong properly to the base of the Lias, that is, to the Hettangian. The unfossiliferous conglomerates and marls attributed to the Trias are directly overlain by limestones and other strata with marine fossils of Liassic facies, among which the ammonite *?Schlotheimia montana* Wähner is represented by one specimen found 30 ft. above the top of the ? Triassic marl. This ammonite belongs to the Marmorea Zone, and is the first known occurrence of an Hettangian ammonite in the North-West of Scotland. With only one specimen found it is not possible to ascertain the thickness of the Marmorea Zone, but an ammonite indicating the Rotiformis Zone was found some 60 ft. above the position of the *Schlotheimia*. Oysters of the group of *Ostrea liassica* and *O. irregularis* are throughout the most abundant fossils. Some are remarkably well preserved and may afford interesting comparisons with the oyster-beds of the classical English Lower Lias localities.

The North-east coast of Skye affords one of the most imposing Lower Oolite sections in Britain. Unfortunately the coast is too precipitous to permit of strictly zonal collecting. However, the main point of interest was ascertained, and this is the remarkable swelling of the zones as compared to the thickness of the same horizons in Mull, where most of the Lower Oolite zones up to the Garantiana Zone are crowded within the short distance of some 70 feet, while in North-east Skye they occupy about 500 feet of strata, and in Raasay about 700 feet. The fauna consists mainly of cephalopods, often unusually large and well preserved. Mr. Buckman's report on this fauna is as follows:—

"In Raasay what has been called Upper Lias Shales belongs to the zones *aalensis-opaliformis;* thus these shales, about 60 feet thick, appertain to the base of the Aalenian or Lower Inferior Oolite. The succeeding *scissum* bed (the Main Ammonite Bed) is richly charged with specimens. The following zone of *murchisonæ* and other zones of the Aalenian and Bajocian (except *niortensis*) are also present, yielding many species of Ammonites.

"A preliminary examination of the Jurassic cephalopods collected in Skye during 1914 has been made, and the following remarks may be offered. The lower beds of the Upper Lias (Whitbian) are much more developed than in Raasay; but there is the same absence of the Yeovilian. No evidence for the *scissum* zone of the Aalenian has been noted; but the *murchisonæ* zone yields a most abundant and varied series of Ludwiginæ (*Ludwigia, Apedogyria, Hyattina, &c.*) represented by magnificently preserved specimens. This is the most ammonitiferous development of the *murchisonæ* zone discovered in the British Isles as yet; but though the number of specimens is so great there are no examples of *Hammatoceras* or of *Erycites*, both of which are

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found in South England; and the omission of these Hammatoceratidæ has an important bearing on the geographical distribution of Ammonite families.

"Little evidence for succeeding zones has been noted until the *sauzei* zone of the Bajocian; this is represented by many beautifully preserved specimens of *Sonninia* with *Poecilomorphus macer*. There are also Ammonites of the *blagdeni* zone from Skye.

"So far as Lias and Inferior Oolite are concerned the deposits of Raasay and Skye rival in richness the classic localities of Yorkshire and South England, and they add some features of their own which have not been found in the deposits of those localities."

A point of interest among the fossils collected by Mr. Tait from the Mull leaf-bed is the presence of mollusc shells, which occur actually in the leaf-bed. They are not sufficiently well preserved to permit identification, yet it seems that they include a *Cyrena*, beside gasteropods.

VI.—PHOTOGRAPHIC WORK.

(1.) England and Wales.

In addition to the photomicrographic and miscellaneous photographic work carried out under the direction of the Petrographical Department, photographs of geological subjects have been taken and added to the collection from the London District, North Wales and Cheshire.

(2.) Scotland.

110 photographs illustrating the geology of Berwickshire, Haddingtonshire, and Sutherlandshire were taken.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

A temporary exhibit has been prepared, under the direction of Dr. Walcot Gibson, to illustrate the memoir on the Concealed Coalfield of Yorkshire and Nottinghamshire.

A new edition of the "Short Guide" to the Museum has been prepared and is now on sale.

Progress has been made with the cataloguing of the Ludlam Collection.

List of Donations during the year 1914.

Associated Portland Cement Manufacturers, Ltd., The (per the British Museum).—A series of Flint Implements.

Barnard, Mrs. T. H.—A polished specimen of marble from a disused quarry at Ardmaddy Bay, Argyllshire.

Bartlett, Dr. B. Pope, M.R.C.S.—Brachiopoda and Mollusca zonally collected from the Chloritic Marl of Wiltshire and Dorset.

Brady, Noel P. Wentworth, Esq.—*Rhadinichthys planti* Traquair, from a boring in the Coal Measures near Goole, Yorkshire.

Brighton Museum, The Curator of.—Specimens of Sussex calcite.

Carruthers, R. G., Esq.—Five specimens of Oil-shale from New Brunswick, Canada.

Ceiriog Granite Co., Ltd., The.—Two 4-inch cubes and seven assorted sizes of "Granite" from the Hendre Quarry, Glyn Ceiriog, Chirk, Denbighshire.

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CUNNINGHAM, A. D., ESQ.—A specimen of Massive Talc from the Transvaal; also a sample of "Verdite" from the same district.

DEWEY, H., ESQ., F.G.S.—A specimen of Quartz Porphyry from Porborough Down, Devonshire; also a specimen of Tourmaline from St. Just, Cornwall.

DICK, ALLAN B., ESQ.—A series of specimens of Kaolinite from various localities and a series of microscopic preparations of the same.

DOUGLAS, J. A., ESQ., M.A., B.Sc.—*Pustula interrupta* I.Thom., from the Carboniferous Limestone of Co. Clare.

EDWARDS, E. W. J., ESQ., A.R.C.S., A.M.I.C.E.—A stone implement from Central Africa.

ELIAS, O. A., ESQ., F.C.S.—A sample of Pitchblende.

GREENLY, E., ESQ., F.G.S.—Eight hundred and eleven micro-slides and specimens of Anglesey rocks.

HALDER, W., ESQ.—A "Chisel" broken in the hole at the Armthorpe boring, and recovered with great difficulty.

HASLUCK, J. W., ESQ.—Firesteels and Flints from Monastir. Also a specimen of marble from Resna, near Ochrida (Serbian Macedonia).

HIND, WHEELTON, ESQ., M.D., B.S., F.R.C.S.—Two specimens of *Pustula* from the Carboniferous Limestone, and three of *Derbyia* from the Millstone Grit.

HOOKER, LADY.—A series of specimens from the Antarctic, collected by the late Sir J. Hooker.

HUTCHINSON, T. ANTHONY, ESQ.—A series of examples of Pumice, Rouge, and Silica, &c., employed in polishing powders.

JIMBO, PROFESSOR.—Specimens of Piedmontite Schist from Otakisan, Shikoku, Japan.

JOHNSTON, MISS M. S.—A series of specimens from the Theban Mountains and the Ghizeh Plateau, Egypt, illustrating "eye-stones" and desert characters. Also a specimen of Eocene Limestone from the Theban Mountains, and a modern "Antiqua" from the stone. Also specimens from the Wenlock Limestone.

KING, W. B. R., ESQ., B.A.—Brachiopoda and Mollusca from Great Shunner Fell, Yorkshire.

LAMPLUGH, G. W., ESQ., F.R.S.—Specimens of Chabazite and Calcite from Australia.

LAPWORTH, DR. H., M.INST.C.E.—A specimen of "Lower" Kinder Scout Grit from Bamford Edge, North Derbyshire.

LEACH, A. L., ESQ.—Fossils from the Millstone Grit near Tenby, and a fragment of a vertebra of *Elephas* from the Pleistocene of Erith Brick Pit.

LIBERIAN DEVELOPMENT CO., LTD., THE.—A series of Concentrates from the Jiblong River, near Banza Ta, Montserrado, Liberia. Also a perfect natural diamond from the same field.

MACDERMID, W., ESQ.—A specimen of sand cemented with pyrite.

MACDONALD, THE HON. GEORGE.—Specimens of oil-shales from the Scorrybreck ground, near Portree, Isle of Skye.

MCKAY, MRS.—Two specimens of volcanic dust.

MCROBERT, LADY.—A suite of rocks from the Eildon Hills and the neighbourhood of Melrose.

MATLEY, DR. C. A.—One hundred and sixty micro-slides and rocks from Anglesey.

MAWSON, SIR DOUGLAS.—Radioactive ore from Mount Painter, Australia.

MOIR, DR. JAMES.—A specimen of a new mineral from Madagascar, MO_3, TiO_2.

MURRAY, R. B., ESQ., B.A.—A series of minerals and rocks from Canada.

NICHOLAS, T. C., ESQ., B.A., F.G.S.—Specimens of (1) Pisolitic iron ore, (2) unweathered mudstone, (3) weathered shale, from the St. Tudwal's Peninsula, Carnarvonshire.

PEILE, MAJOR A. J., R.A.—*Nipadites*, fish remains, and fragments of wood from the London Clay of Shoeburyness.

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PERRY, H. W., ESQ.—Specimens of Chrysoberyl and two rocks from Southern India.

PIERSON, DR. L. V.—A set of type-rocks (21) from the Highwood Mountains, Montana.

REID, CLEMENT, ESQ., F.R.S.—Types of seeds from the Forest Bed of Pakefield, and seeds from the Arctic Bed of Beeston, Norfolk.

RICHARDSON, L., ESQ., F.R.S.E.—*Zigzagiceras* from the Fuller's Earth, near Bath, and Ammonites from the Lias of Timsbury Sleight, near Bath.

RINNE, A., ESQ.—A set of samples of synthetic marbles. (Batzbacher Marmorplatten).

SHERLOCK, DR. R. L., A.R.C.S.—Types of Foraminifera from the Speeton Clay of Yorkshire.

TIMMINS, A., ESQ., A.M.I.C.E.—*Axinus truncatus* (King), from the Permian, near Manchester.

TUCKETT, H. E., ESQ.—One three-inch "Shot Crown."

VAUGHAN-STEVENS, A., ESQ.—Specimens of Wulfenite from Spain.

VERDITE MINES, LTD., THE.—Specimens of Magnesite.

WALFORD, E. A., ESQ.—*Trigonia beesleyana* Lyc. and *T. brodiei* Lyc. from the Inferior Oolite.

WARREN, S. H., ESQ., and CLEMENT REID, ESQ., F.R.S.—Plants from the Arctic Bed of the Lea Valley.

WHITE, H. J. OSBORNE, ESQ.—Flint implements from Lee-on-Solent.

WITHERS, T. H., ESQ.—Brachiopoda from the Chalk of various localities.

YOUD, H., ESQ.—Specimens of Autunite.

ACQUIRED BY EXCHANGE DURING THE YEAR 1914.

DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND—A polished slab of Ball Granite from Co. Donegal.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

(A.) ENGLAND AND WALES.

I.—MAPS.

(*a*) ONE-INCH MAPS.

New Series; Colour-printed.

Sheet 112, Chesterfield (Drift). Price 1*s.* 6*d.*

(*b*) SIX-INCH REFERENCE MAPS.

The following 42 standard copies of six-inch quarter-sheets have been made from the field copies, and are available for reference:—

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II.—MEMOIRS.

Published Memoirs.

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APPENDIX I.

The Whittlesford Boring.

By A. Strahan, Sc.D., LL.D., F.R.S.

A boring, in progress in May, 1914, at the Cabin, 1 mile west of Whittlesford Station, has furnished a notable addition to our knowledge of the Cam Valley. The section supplied by R. Maynard, the engineer by whom the work was carried out, showed the following details. The remarks in square brackets have been added to Mr. Maynard's account:—

Boring at the Cabin, Whittlesford.

[Height above O.D. about 120 feet.]

		Thickness. Ft.	Depth Ft.
	Top soil and gravel	15	15
[Glacial Drift]	Clunch (water at 120 ft. depth)	142	157
	Blue Clay	147	304
	Marl	59	363
	Lower Greensand (a brilliant grass-green sand when fresh, but losing its colour considerably)	7	370
	Rock (light colour)	34	404
	Various alternate seams of soft and hard materials varying from pale-blue to terra-cotta	46	450
	Rock, chocolate, containing marcasite in nodules		to 455
	Some fragments of flint		at 455

Specimens furnished by Mr. Maynard showed that the 'blue clay' is a stiff clay of pale bluish colour containing minute pellets of chalk. The 'marl,' 59 feet thick, is a similar material, of a slightly darker tint. It contained a minute fragment of an ammonite, and dark phosphatic nodules.

The 'Lower Greensand' is a brown ochry material, with no trace of green, the colour presumably having been due to an iron salt which has decomposed. It contains rounded grains of quartz and kidney-shaped grains of iron oxide, but no glauconite. The 'rock (light colour)' is a silty material of a pale-greenish hue. From a depth of 450 feet a specimen of clay mottled pale-blue and pale-red was furnished, and from 455 feet a small chip of chalk-flint.

It was noticeable that the 'rock (light colour)' and the mottled red and blue clay resembled material found in a deep drift-filled channel near Henlow, in Bedfordshire.[1] The mottled clays in the two channels are almost identical in character.

The boring started at an estimated height of 35 feet above the Melbourn Rock. It should therefore have reached the base of

[1] 'Summary of Progress for 1912' (*Mem. Geol. Surv.*), 1913, p. 89.

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the chalk at about 400 feet and the base of the Gault at about 550 feet depth.

With respect to the flints at a depth of 455 feet, Mr. Maynard remarks that "we cannot quite see how they got them from the surface, as we are piped down to 370 feet, nor could they reasonably fall in unless deliberately dropped in the pipe." This he regarded as 'very improbable.'

The only previous boring near Whittlesford which suggested a buried channel was situated between the Railway Station and the river at a height of about 80 ft. above the sea. Rock was not reached at a depth of 50 feet.[1]

The Whittlesford section must be considered in connection with the series of borings made along the valley of the Cam, which were described by Mr. Whitaker in 1890.[2]

The series, supplemented by information given in the Geological Survey Memoir on the Water Supply of Essex, is taken in order from south to north in the following table.

The elevations are given in feet and the signs + and — indicate above and below Ordnance Datum respectively:—

	Quendon Hall.	Newport.	Wenden.	Littlebury.	Great Chesterford.	Whittlesford.
Elevation of surface	300	200	230	157	142	120
Depth to base of drift	142	more than 340	272	more than 218	156	more than 455
Elevation of rock-surface	+158	more than —140	—40	more than —61	—14	more than —335

It was anticipated in 1890 by Mr. G. Ingold, to whom much of the information respecting these borings was due, that the channel reached northward to Whittlesford, but that a hollow extending to a depth of more than 335 feet below the level of the sea should exist there is surprising. No outlet to the sea of similar depth is known and the hollow would presumably, in the absence of Drift, form a lake.

APPENDIX II.

Catalogue of Types and Figured Specimens of British CRETACEOUS LAMELLIBRANCHIATA preserved in the Museum of Practical Geology, London.

By H. A. Allen, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species or variety. The figures in brackets, [7009], correspond to the number in the Museum Register; those preceded by "G.S." refer to specimens formerly in the collection of the Geological Society.

[1] 'The Geology of the Country between and South of Bury St. Edmunds and Newmarket' (*Mem. Geol. Surv.*), 1886, p. 20.

[2] *Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p. 333.

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The following abbreviations are employed:—

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.
Mon. Pal. Soc.: Monographs of the Palæontographical Society, London.
"British fossil Trigoniae," by John Lycett.
"Cretaceous Lamellibranchia of England," by Henry Woods.
Trans. G. S.: Transactions of the Geological Society of London.
Q. J. G. S.: Quarterly Journal of the Geological Society of London.
(The dates quoted refer to year of issue only.)

Anomia convexa, J. de C. Sow. **T.**

J. de C. Sowerby, Trans. Geol. Soc., Ser. 2, vol. iv., 1836, pl. xiv., f. 7, p. 338. Refigured, H. Woods, Mon. Pal. Soc., 1899, pl. v., f. 10, p. 29.
Lower Greensand. [G.S. 2032] Shanklin.

Anomia laevigata, J. de C. Sow. **T.**

J. de C. Sowerby, Trans. Geol. Soc., Ser. 2, vol. iv., 1836, pl. xiv., f. 6a, p. 338. Refigured, H. Woods, Mon. Pal. Soc., 1899, pl. v., f. 6, p. 29.
Lower Greensand (Hythe Beds). [6414] Lympne.
H. Woods, Mon. Pal. Soc., 1899, pl. v., f. 7, p. 29.
Lower Greensand (Atherfield Beds). [6415] Peasemarsh.
H. Woods, Mon. Pal. Soc., 1899, pl. v., f. 8, p. 29.
Lower Greensand. [6417] Punfield.

Anomia pseudoradiata, d'Orb.

H. Woods, Mon. Pal. Soc., 1899, pl. v., f. 3, p. 27.
Lower Greensand. [26702] Atherfield.

Anomia sp., cf. pseudoradiata, d'Orb.

H. Woods, Mon. Pal. Soc., 1899, pl. v., f. 11, p. 30.
Gault. [6440] Black Ven.

Anomia radiata, J. de C. Sow. **T.**

J. de C. Sowerby, Trans. Geol. Soc., Ser. 2, vol. iv., 1836, pl. xiv., f. 5, p. 338.
Lower Greensand. [G.S. 2029] Sandgate, near.

Arca exaltata? Nilsson.

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 5, p. 245.
Lower Greensand. [G.S. *p.* 22] S. of Culver Cliff, Isle of Wight.

Arca radiata, Portlock. **T.**

J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 442. Renamed **Arca albaecretae,** Tate. **T.** R. Tate, Q. J. G. S., vol, xxi., 1865, p. 40.
Upper Chalk. [18668] Ireland.

Astarte elongata, d'Orb.

H. Woods, Mon. Pal. Soc., 1906, pl. xiv., figs. 2, 3, p. 102.
Lower Greensand. [13176, 13181] Seend.

Astarte (Eriphyla) obovata, J. de C. Sow.

H. Woods, Mon. Pal. Soc., 1906, pl. xvi., f. 3, p. 113.
Upper Greensand. [13184] Blackdown.

Astarte (Eriphyla) striata, J. de C. Sow.

H. Woods, Mon. Pal. Soc., 1906, pl. xvii., figs. 3, 6, p. 116.
Upper Greensand. [13187, 13188] Blackdown.

Avicula depressa, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 7, p. 247. Refigured as **Pteria (Pseudoptera) subdepressa** (d'Orb.). H. Woods, Mon. Pal. Soc., 1905, pl. ix., f. 1, p. 63.
Lower Greensand. [G.S. 2050] Atherfield.

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Avicula ephemera, Forbes. T.

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 6, p. 247.
Lower Greensand. [G.S. 2051, 2052] Atherfield.

Avicula lanceolata, Forbes (*non* Sow.). T.

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 8, p. 247.
Lower Greensand. [G.S. 2057] Atherfield.

Avicula simulata, Baily. T.

W. H. Baily in J. W. Salter, Q. J. G. S., vol. xiii., 1857, pl. ii., f. 5, p. 86.
Upper Greensand. [21102] Moreseat, Aberdeenshire.

Barbatia marullensis (d'Orb.).

H. Woods, Mon. Pal. Soc., 1899, pl. vii., figs. 5, 7, p. 38.
Gault. [1630, 6559] Folkestone.

Cardita cottaldina, d'Orb.

H. Woods, Mon. Pal. Soc., 1906, pl. xviii., f. 15, p. 126.
Chloritic Marl. [14348] Toller Fratrum.

Cardita? fenestrata (Forbes).

H. Woods, Mon. Pal. Soc., 1906, pl. xviii., f. 2, p. 121.
Lower Greensand (Perna Bed). [14360] Atherfield.

Cardium (Hemicardium?) austeni, Forbes. T.

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 3, p. 244.
Lower Greensand. [G.S. 2152] Peasemarsh.

Cardium benstedi, Forbes. T.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 244.
Lower Greensand. [G.S. 2124] Maidstone.

Cardium cornuelianum, d'Orb.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 243.
Lower Greensand. [G.S. 2139] Peasemarsh.

Cardium gibbosum, Tate. T.

R. Tate, Q. J. G. S., vol. xxi., 1865, pl. iv., f. 6, p. 39.
Upper Greensand (Hibernian Greensand).
[23277] Colin Glen, Belfast.

Cardium ibbetsoni, Forbes. T.

E. Forbes, Q. J. G. S., vol. i., 1845, pl. ii., f. 9, p. 243.
Lower Greensand. [G.S. 2136] Atherfield.

Cardium sphaeroideum, Forbes. T.

E. Forbes, Q. J. G. S., vol. i., 1845, pl. ii., f. 8, p. 243.
Lower Greensand. [G.S.ρ21] Culver, Isle of Wight.

Cardium sp.

H. Woods, Mon. Pal. Soc., 1908, pl. xxxii., f. 12a, b, p. 204.
Lower Greensand. [21273, 21272] Seend.

Clementia (Flaventia) ovalis (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1908, pl. xxix, figs. 20, 26, p. 191.
Greensand. [19778, 19814] Blackdown.

Corbis corrugata (J. Sow.).

E. Forbes, Q. J. G. S., vol. i., 1845, p. 239.
Lower Greensand. [G.S. 2144] Atherfield.

Corbis ? fibrosa, Forbes. T.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 239.
Lower Greensand. [G.S. 2154] Peasemarsh.

Corbula gaultina, Pict. and Camp.

H. Woods, Mon Pal. Soc., 1908, pl. xxxiv., figs. 15, 16, p. 214.
Gault. [22727, 22728] Folkestone.

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Corbula sp.

H. Woods, Mon. Pal. Soc., 1908, pl. xxxiv., f. 13, p. 213.
Lower Greensand. [22723] Punfield Cove.

Crassatellites divisiensis, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1906, pl. xix, f. 1, p. 128.
Upper Greensand. [16750] Devizes.

Cuspidaria sabaudiana (Pict. and Camp.).

H. Woods, Mon. Pal. Soc., 1909, pl. xliii., f. 6, p. 259.
Gault. [23821] Folkestone.

Cypricardia? undulata, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 1, p. 242. Refigured as **Modiola undulata** (Forbes). H. Woods, Mon. Pal. Soc., 1900, pl. xvii, f. 3, p. 100.
Lower Greensand. [G.S. 2088] Atherfield.

Cyprimeria (Cyclorisma) faba (J. de Sow.).

H. Woods, Mon. Pal. Soc., 1908, pl. xxix., f. 11, p. 187.
Greensand. [19774] Blackdown.

Cyprimeria (Cyclorisma) rotomagensis (d'Orb.).

H. Woods, Mon. Pal. Soc., 1908, pl. xxix, f. 4, p. 186.
Chloritic Marl. [18735] Woolcombe, Dorset.

H. Woods, Mon. Pal. Soc., 1908, pl. xxix, f. 5, p. 186.
Chloritic Marl. [18746] Maiden Bradley.

Cyprina (Venilicardia) angulata (J. Sow.).

H. Woods, Mon. Pal. Soc., 1907, pl. xxii., f. 4, p. 141.
Greensand. [26006] Blackdown.

H. Woods, Mon. Pal. Soc., 1907, text fig. 23, p. 142.
Greensand. [18698] Haldon.

Cyprina fergusoni, Salt. **T.**

J. W. Salter, Q. J. G. S., vol. xiii., 1857, pl. ii., f. 7, p. 87.
Upper Greensand. [18888] Moreseat, Aberdeenshire.

Cyprina meyeri, Woods.

H. Woods, Mon. Pal. Soc., 1913, pl. lxii, f. 3, p. 427.
Lower Greensand (Perna Bed). [16747] Sandown, I.W.

Cyprina (Venilicardia) protensa, Woods.

H. Woods, Mon. Pal. Soc., 1907, pl. xxi., f. 5, p. 137.
Lower Greensand. [16744] Atherfield.

Dianchora? guttata, Sharpe. **T.**

D. Sharpe, Q. J. G. S., vol. x., 1853, pl. vi., f. 4, p. 197.
Lower Greensand. [G.S.*p*44] Faringdon.

Dimyodon nilssoni, *vide* **Plicatula sigillina.**

Exogyra conica (J. Sowerby).

H. Woods, Mon. Pal. Soc., 1913, text-figs. 238, 239, p. 412.
Gault. [20873] Folkestone.

H. Woods, Mon. Pal. Soc., 1913, text-fig. 240, p. 412.
Upper Greensand. [20999] Devizes.

Exogyra digitata (J. Sowerby).

H. Woods, Mon. Pal. Soc., 1913, text-figs. 251, 252, p. 418.
Upper Greensand (Zone of *Pecten asper*).
[20956, 20954] Evershot, Dorsetshire.

Exogyra sinuata (J. Sowerby).

H. Woods, Mon. Pal. Soc., 1913, text-figs. 208, 209, p. 402.
Lower Greensand (Hythe Beds). [20821] Hythe.

Exogyra tuberculifera, Koch and Dunker.

H. Woods, Mon. Pal. Soc., 1913, pl. lxi., figs. 9–11, p. 404.
Lower Greensand (Hythe Beds). [25968, 25958, 25957] Lympne.

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Gervillia linguloides, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 9, p. 246.
Lower Greensand. [G.S. 2054] Atherfield.

Gervillia rostrata (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1905, pl. xi., f. 13, p. 83.
Greensand. [10784] Blackdown.

H. Woods, Mon. Pal. Soc., 1905, pl. xi., f. 22, p. 83.
Greensand. [10783] Haldon.

Gervillia solenoides, J. de C. Sow. **T.**

J. de C. Sowerby, Min. Conchology, vol. vi., 1826, pl. 510, f. 1, p. 14.
Upper Greensand. [G.S. 1555] Lyme Regis.

Grammatodon carinatus (J. Sowerby).

H. Woods, Mon. Pal. Soc., 1899, pl. viii., f. 7, p. 45.
Gault. [1632] Folkestone.

Gryphaea harpa, Goldfuss, *var.* γ. **semiplicata,** Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 12, p. 250.
Lower Greensand. [25984] Atherfield.

Gyropleura cornucopiae (d'Orb.).

H. Woods, Mon. Pal. Soc., 1908, pl. xxxiii., f. 7, p. 208.
Chloritic Marl. [22440] Melbury Park.

Hinnites favrinus, Pictet and Roux.

H. Woods, Mon. Pal. Soc., 1903, text-fig. 6, p. 221.
Lower Greensand (Perna Bed). [G.S. 2022] Atherfield.

Hinnites leymerii, Desh. in Leym.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 250. Refigured as **Hinnites favrinus,** Pictet and Roux, H. Woods, Mon. Pal. Soc., 1903, text-fig. 7, p. 222.
Lower Greensand (Perna Bed). [8444] Atherfield.

Inoceramus balticus, Boehm.

H. Woods, Mon. Pal. Soc., 1912, text-fig. 53, p. 295.
Upper Chalk. [25509] Brighton.

Inoceramus concentricus, Park.

H. Woods, Mon. Pal. Soc., 1911, pl. xlvi., f. 8, p. 265.
Greensand. [21183] Blackdown.

Inoceramus concentricus, Park., *var.* **subsulcatus,** Wiltsh.

H. Woods, Mon. Pal. Soc., 1911, pl. xlvii., figs. 5, 14, p. 268.
Gault. [21154, 21153] Folkestone.

Inoceramus costellatus, Woods.

H. Woods, Mon. Pal. Soc., 1912, pl. liv., figs. 6, 7, p. 336.
Chalk Rock. [25510, 25511] Blount's Farm, Marlow.

Inoceramus crippsi, Mant.

H. Woods, Mon. Pal. Soc., 1911, pl. xlviii., f. 2, p. 273.
Upper Greensand. [18898] Warminster.

Inoceramus lamarcki, Park.

H. Woods, Mon. Pal. Soc., 1912, text-fig. 85, p. 325.
Upper Chalk. [21237] ?

Inoceramus neocomiensis, d'Orb.

H. Woods, Mon. Pal. Soc., 1911, pl. xlv., f. 2, p. 262.
Lower Greensand (Hythe Beds). [21133] Lympne.

Inoceramus (Mytilites) problematicus (Schloth.).

R. Etheridge, M. G. S., 51 S. W. (Cambridge), 1881, pl. iii., figs. 9, 10, 11, p. 143.

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Middle Chalk (*Rhyn. cuvieri* Zone).
[21230–21232] Missleton Hill, Fulborn, Cambridge.

Isoarca obesa (d'Orbigny).

H. Woods, Mon. Pal. Soc., 1899, pl. xiii., f. 8, p. 65.
Chloritic Marl. [6349] Ball Wood, Dorsetshire.

Lima (Limea?) composita (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1904, pl. vii., figs. 24, 25, 26, p. 53.
Upper Greensand. [8786, 8783, 8784] Warminster.

Lima elegans (Nilsson).

J. W. Salter, Q. J. G. S., vol. xiii., 1857, pl. ii., f. 3, p. 85.
Upper Chalk. [20703] Moreseat, Aberdeen.

Lima expansa, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 11, p. 249.
Atherfield Clay? [G.S. 2058] Hythe?

Lima farringdonensis, Sharpe. **T.**

D. Sharpe, Q. J. G. S., vol. x., 1854, pl. vi., f. 2, p. 198. Redescribed, H. Woods, Mon. Pal. Soc., 1904, p. 30.
Lower Greensand. [26400] Seende.

Lima galliennei, d'Orb.

H. Woods, Mon. Pal. Soc., 1904, pl. ii., fig. 1, p. 3.
Upper Greensand. [8798] Devizes.

Lima lingua, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., fig. 10, p. 249.
Atherfield Clay? [G.S. 2506] Hythe?

Lima (Acesta) longa, F. A. Roemer.

H. Woods, Mon. Pal. Soc., 1904, pl. v., fig. 12, p. 25.
Speeton Series (Upper Part). [8781] Speeton.

Lima (Plagiostoma) meyeri, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1904, pl. iv., fig. 2, text-fig. 4, p. 15.
Upper Greensand. [8839, 8838] Warminster.

Lima scabrissima, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1904, pl. ii., figs, 8, 9, p. 7.
Upper Greensand. [8816, 8815] Warminster.

Lima subovalis, J. de C. Sow.

H. Woods, Mon. Pal. Soc., 1904, pl. ii., figs. 4 and 5, p. 5.
Upper Greensand. [8805, 8804] Warminster.

Lima (Limatula) tombeckiana, d'Orb.

H. Woods, Mon. Pal. Soc., 1904, pl. vii., figs. 7, 8, 9, p. 45.
Hythe Beds. [8821, 8822, 8824] Court at Street, nr. Lympne.

Lima (Limatula) tombeckiana? d'Orb.

H. Woods, Mon. Pal. Soc., 1904, pl. vii., fig. 10, p. 46.
Upper Greensand. [8818] Charmouth.

Lima (Mantellum) sp.

H. Woods, Mon. Pal. Soc., 1904, pl. vi., fig. 16, p. 40.
Chloritic Marl. [7896] Chardstock.

Limopsis albiensis, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1899, pl. xv., figs. 1-4, p. 71.
Gault. [18689–18692] Folkestone.

Limopsis texturata, Salt. **T.**

J. W. Salter, Q. J. G. S., vol. xiii., 1857, pl. ii., f. 6, p. 85.
Greensand. [19855, 19856] Moreseat, Aberdeenshire.

Lucina downesi, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1907, pl. xxiv., f. 15, p. 155.
Greensand. [19771] Blackdown.

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Lucina globiformis, Leymerie.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 240.
Lower Greensand. [G.S. 2157] Atherfield?

Lucina? globosa, J. de C. Sow.

J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., pl. xi., f. 2, p. 335.
Chloritic Marl. [G.S. 1538] Western Lines, Isle of Wight.

Lucina? sculpta, Phillips.

H. Woods, Mon. Pal. Soc., 1907, pl. xxiv., f. 7, p. 153.
Gault (Bed vi.). [19761] Folkestone.

Lucina sp.

H. Woods, Mon. Pal. Soc., 1907, pl. xxiv., f. 4, p. 152.
Lower Greensand. [19719] Atherfield.

Mactra angulata, J. de C. Sow.

H. Woods, Mon. Pal. Soc., 1907, pl. xxvii., figs. 19, 23, p. 177.
Greensand. [20714, 20717] Blackdown.

Martesia constricta (Phillips).

H. Woods, Mon. Pal. Soc., 1909, pl. xxxviii., figs. 7, 10, p. 231.
Gault. [23486, 23487] Folkestone.

Martesia prisca (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1909, pl. xxxviii., f. 11, p. 232.
Lower Greensand. [23474] Maidstone.

Modiola flagellifera (Forbes).

H. Woods, Mon. Pal. Soc., 1900, pl. xvii., f. 2, p. 99.
Upper Greensand. [6658] Black Ven.

Modiola lineata, J. de C. Sow. **T.**

J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., 1836, pl. xiv., f. 2a, b, p. 338. Redescribed as **Mytilus (Modiolus) asper.** E. Forbes, Q. J. G. S., vol. i., 1845, p. 248. Fig. 2b (ρ19) refigured as **Septifer lineatus** (J. de C. Sow.), H. Woods, Mon. Pal. Soc., 1900, pl. xviii., f. 3, p. 106.
Lower Greensand. [G.S. ρ19, ρ18] Hythe.

Modiola undulata, *vide* **Cypricardia.**

Modiola (Brachydontes) vectiensis, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1900, pl. xvii., f. 7, p. 102.
Lower Greensand. [G.S. 2092] Peasemarsh.

H. Woods, Mon. Pal. Soc., 1900, pl. xvii., f. 8, p. 102.
Lower Greensand (Atherfield Beds). [6690] Littleton Pit, Guildford.

Mytilus (Modiolus) bellus (J. de C. Sow.).

E. Forbes, Q. J. G. S., vol. i., 1845, p. 248.
Lower Greensand. [G.S. 2075] Atherfield.

Mytilus (Modiolus) simplex, Deshayes.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 248. Figured as **Modiola subsimplex** (d'Orb.) H. Woods, Mon. Pal. Soc., 1900, pl. xvi., f. 10, p. 97.
Lower Greensand. [G.S. 2078] Atherfield.

Nucula albensis, d'Orb.

H. Woods, Mon. Pal. Soc., 1899, pl. iv., f. 9, p. 24.
Gault (Zone vi.). [1638] Folkestone.

Nucula apiculata, J. de C. Sow.

? J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., 1836, pl. xvii., f. 10, p. 342. Refigured as **Nucula impressa,** J. de C. Sow. H. Woods, Mon. Pal. Soc., 1899, pl. iv., f. 8, p. 23.
Greensand. [G.S. 1564] Blackdown.

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Nucula derancei, Price. **T.**

F. G. H. Price, Q. J. G. S., vol. xxx., 1874, pl. xxv., f. 7, p. 358.
Gault. [18466] Folkestone.

Nucula obtusa, J. de C. Sow.

J. S. Gardner, Q. J. G. S., vol. xl., 1884, pl. iv., figs. 1, 2, p. 126. Refigured, H. Woods, Mon. Pal. Soc., 1899, pl. iv., figs. 3, 4, p. 22.
Greensand. [18541, 6351] Blackdown.

Nucula pectinata, J. Sow., *var.* **cretae,** Gard. **T.**

J. S. Gardner, Q. J. G. S., vol. xl., 1884, p. 132. Figured, H. Woods, Mon. Pal. Soc., 1899, pl. iii., figs. 14, 15, p. 18.
Greensand. [6449, 6450] Blackdown.

Nucula spathulata, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. iii., f. 4, p. 245. Refigured as **Nuculana spathulata** (Forbes). H. Woods, Mon. Pal. Soc., 1899, pl. i., f. 1, p. 1.
Atherfield Clay. [G.S. 2112] Atherfield.

Nuculana speetonensis, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1899, pl. i., figs. 6, 7, p. 3.
Speeton Clay. [6412, 21418] Speeton.

Ostrea boucheroni, Coquand.

H. Woods, Mon. Pal. Soc., 1913, pl. lx., f. 8, p. 391.
Upper Chalk (Zone of *M. coranguinum*). [25977] Gravesend.

Ostrea canaliculata (J. Sowerby).

H. Woods, Mon. Pal. Soc., 1913, pl. lvi., f. 2, p. 375.
Gault. [20819] Folkestone.

Ostrea diluviana, Linnaeus.

H. Woods, Mon. Pal. Soc., 1913, text-figs. 100–103, p. 348.
Lower Greensand. [25802, 25790, 25795, 25793] Atherfield.

H. Woods, Mon. Pal. Soc., 1913, text-figs. 120, 121, p. 350.
Upper Greensand (Zone of *Pecten asper*). [25814, 25812] Devizes.

H. Woods, Mon. Pal. Soc., 1913, text-fig. 123, p. 353.
Upper Greensand (Zone of *Schl. rostrata*). [25820] Devizes.

Ostrea incurva, Nilsson.

H. Woods, Mon. Pal. Soc., 1913, pl. lix., f. 12, p. 388.
Upper Chalk (Zone of *Bel. mucronata*). [25983] Norwich.

Ostrea vesicularis, Lam.

H. Woods, Mon. Pal. Soc., 1913, text-figs. 143–145, p. 367.
Upper Greensand (Zone of *Pecten asper*). [25950, 25948] Warminster.

Ostrea vesiculosa (J. Sowerby):

H. Woods, Mon. Pal. Soc., 1913, pl. lv., f. 11, p. 374.
Upper Greensand (Zone of *Pecten asper*). [25942] Warminster.

H. Woods, Mon. Pal. Soc., 1913, pl. lv., figs. 12–14; pl. lvi., f. 1, p. 374.
Upper Greensand (Zone of *Schl. rostrata*).
[25936] Isle of Wight; [25932] Potterne; [25938, 25937] Dinton.

Panopaea elongata, Forbes.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 238.
Lower Greensand. [G.S. 2193] Pulborough.

Panopaea mandibula (J. Sow.), *var.* β, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, p. 238.
Lower Greensand. [G.S. 2223] Atherfield.

Panopaea neocomiensis, Leym.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 238.
Lower Greensand. [27031] Atherfield.

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Panopaea plicata (J. de C. Sow.), *var.* β, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, p. 238.
Lower Greensand. [G.S. 2192] Atherfield.

Panopaea?

E. Forbes, Q. J. G. S., vol. i., 1845, p. 238.
Lower Greensand. [G.S. 2200] Reigate.

Pecten (Neithea) aequicostatus, Lam.

H. Woods, Mon. Pal. Soc., 1903, pl. xl., f. 8, p. 208.
Upper Greensand. [G.S. 1530] Worbarrow.

Pecten (Æquipecten) arlesiensis, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1902, pl. xxxvii., figs. 10, 11, p. 194.
Chalk Marl. [562, 20516] Folkestone.

Pecten circularis, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, p. 249.
Lower Greensand. [G.S. 2030] Whale Chine, Isle of Wight.

Pecten (Neithea) cometa (d'Orb.).

H. Woods, Mon. Pal. Soc., 1903, pl. xxxix., figs. 9, 10, p. 200.
Upper Greensand. [8278, 8445] Warminster.

Pecten (Camptonectes) curvatus, Geinitz.

H. Woods, Mon. Pal. Soc., 1902, pl. xxix., f. 7, p. 159.
Greensand. [20357] Great Haldon.

Pecten (Neithea) morrisi, Pict. and Ren.

H. Woods, Mon. Pal. Soc., 1903, pl. xxxix., figs. 11, 12, p. 201.
Lower Greensand (Hythe Beds). [8364, 8446] Lympne.

Pecten (Syncyclonema) orbicularis, *var.* **haldonensis,** Woods. **T.**

H. Woods, Mon. Pal. Soc., 1902, pl. xxvii., f. 4, p. 151.
Greensand (Blackdown). [991] Kingskerswell.

Pecten (Æquipecten) pulchellus, Nilss.

H. Woods, Mon. Pal. Soc., 1902, pl. xxxvii., f. 12, p. 194.
Upper Chalk. [8013] Trimingham.

Pecten (Neithea) quinquecostatus, J. Sow.

H. Woods, Mon. Pal. Soc., 1903, pl. xxxix., f. 16, p. 202.
Upper Greensand. [8419] Warminster.

H. Woods, Mon. Pal. Soc., 1903, pl. xxxix., f. 17, p. 202.
Upper Chalk. [8362] Gravesend.

Pecten (Chlamys) robinaldinus, d'Orb.

H. Woods, Mon. Pal. Soc., 1902, pl. xxxv., figs. 4, 10, p. 181.
Upper Greensand. [7418, 7407] Warminster.

Pecten (Neithea) striatocostatus? Goldf.

H. Woods, Mon. Pal. Soc., 1903, pl. xli., figs. 9, 10, p. 217.
Upper Chalk. [9042, 9043] Trimingham.

Pecten (Chlamys) subacutus, Lam.

H. Woods, Mon. Pal. Soc., 1902, pl. xxxi., f. 8, p. 169.
Greensand. [6683] Haldon.

Pectunculus sublaevis, J. de C. Sowerby.

H. Woods, Mon. Pal. Soc., 1899, pl. xiv., figs. 6, 7, p. 67.
Greensand. [6573, 18934] Blackdown.

Pectunculus umbonatus, J. de C. Sow.

J. W. Salter, Q. J. G. S., vol. xiii., 1857, p. 86.
Greensand. [18986] Moreseat, Aberdeenshire.
H. Woods, Mon. Pal. Soc., 1899, pl. xiv., f. 12, p. 69.
Greensand. [6572] Blackdown.

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Perna rauliniana, d'Orb.

H. Woods, Mon. Pal. Soc., 1905, pl. xii., figs. 8, 9, p. 92.
Gault. [1605, 12638] Folkestone.

Perna ricordeana, d'Orb.

H. Woods, Mon. Pal. Soc., 1905, text-f. 16, p. 90.
Lower Greensand (Perna Bed). [12351] Atherfield

Pholadomya? agassizi, Forbes.

E. Forbes, Q. J. G. S., vol. i., 1845, p. 239.
Lower Greensand. [G.S. 2220] Hythe.
T.

Pholadomya cordata, Tate.

R. Tate, Q. J. G. S., vol. xxi., 1865, pl. iv., f. 1, p. 40.
Upper Chalk (White Limestone). [23629] Lisburn, Co. Antrim.

H. Woods, Mon. Pal. Soc., 1909, pl. xlii., f. 2, p. 253.
Upper Chalk (White Limestone). [23628] Tamlagt, Co. Derry.
T.

Pholadomya obliquissima, Tate.

R. Tate, Q. J. G. S., vol. xxi., 1865, pl. iv., f. 3, p. 40.
Upper Chalk (White Limestone). [23631] Lisburn, Co. Antrim.
T.

Pholadomya speetonensis, Woods.

H. Woods, Mon. Pal. Soc., 1909, pl. xli., f. 4, p. 248.
Lower Greensand. (23620] Speeton.
T.

Pholadomya stewarti, Tate.

R. Tate, Q. J. G. S., vol. xxi., 1865, pl. iv., f. 2, p. 41.
Upper Chalk (White Limestone). [23630] Lisburn, Co. Antrim.

Pinna robinaldina, d'Orb.

H. Woods, Mon. Pal. Soc., 1906, pl. xii., f. 14, p. 97.
Lower Greensand. [G.S. 2100] Atherfield.

H. Woods, Mon. Pal. Soc., 1906, pl. xiii., f. 1, p. 97.
Lower Greensand. [12636] Isle of Wight.

Pinna sp.

H. Woods, Mon. Pal. Soc., 1906, pl. xiii., f. 3, p. 99.
Gault. [12641] Folkestone.
T.

Plicatula deltoidea, Tate.

R. Tate, Q. J. G. S., vol. xxi., 1865, pl. iii., f. 5, p. 39.
Glauconitic Sands. [20205] Whitehead, N. of Ireland.
T.

Plicatula inaequidens, Sharpe.

D. Sharpe, Q. J. G. S., vol. x., 1854, pl. vi., f. 3, p. 197.
Lower Greensand. [G.S. 7559] Faringdon.

Plicatula placunea, Lam.

H. Woods, Mon. Pal. Soc., 1901, pl. xxv., figs. 1-4, p. 134.
Lower Greensand. [6781, 20186-20188] Lympne.

Plicatula sigillina, S. P. Woodw.

H. Woods, Mon. Pal. Soc., 1901, pl. xxvi., fig. 22, p. 143. Referred to **Dimyodon nilssoni,** Hagenow. H. Woods, Mon. Pal. Soc., 1903, p. 225.
Upper Chalk (Zone of *M. cortestudinarium*). [20284] Chatham.

Pteria (Pseudoptera) gaultina, Woods.

H. Woods, Mon. Pal. Soc., 1905, pl. ix., f. 11, p. 67.
Gault. [10780] Black Ven.

Pteria subdepressa *vide* **Avicula.**

Pteria (Oxytoma) tenuicostata (F. A. Roemer).

H. Woods, Mon. Pal. Soc., 1905, pl. viii., figs. 19, 20, p. 61.
Upper Chalk. [10788, 12620] Coddenham, Suffolk.

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Pteria (Oxytoma) sp.

H. Woods, Mon. Pal. Soc., 1905, pl. viii., f. 15, p. 60.
Lower Chalk (Totternhoe Stone). [2338] Hitchin.

Radiolites mortoni, Mant.

S. P. Woodward, Q. J. G. S., vol. xvi., 1855, p. 47.
Lower Chalk. [27033] Sussex?

Septifer lineatus (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1900, pl. xviii., figs. 1, 2, 4, p. 106.
Lower Greensand. [20049-20051] Lympne.

H. Woods, Mon. Pal. Soc., 1900, pl. xviii., f. 5, p. 106.
Chloritic Marl. [6596] Chardstock.

H. Woods, Mon. Pal. Soc., 1900, pl. xviii., f. 6, p. 106.
Upper Greensand. [6773] Kempstone Rocks, Sidmouth.
See also **Modiola lineata.**

Solecurtus warburtoni, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. ii., f. 1, p. 237.
Lower Greensand (Crackers). [G.S. 2218, 27030] Atherfield.

Solecurtus warburtoni, Forbes, *var.?*

E. Forbes, Q. J. G. S., vol. i., 1845, p. 238.
Lower Greensand (Crackers). [G.S. 2204] Atherfield.

Sphaera corrugata, J. Sow.

H. Woods, Mon. Pal. Soc., 1907, text-fig. 26, p. 159.
Lower Greensand. [19716] Near Hythe.

Sphaera sp.

H. Woods, Mon. Pal. Soc., 1907, pl. xxv., f. 3, p. 159.
Chalk Marl. [7899] Chard.

Spondylus dutempleanus, d'Orb.

H. Woods, Mon. Pal. Soc., 1901, pl. xxiii., f. 4, p. 125.
Upper Chalk. [7447] Trimingham.

Spondylus striatus (J. Sow.).

H. Woods, Mon. Pal. Soc., 1901, pl. xxi., f. 1, p. 119.
Upper Greensand. [6836] Warminster.

Teredo gaultina, Woods. **T.**

H. Woods, Mon. Pal. Soc., 1909, pl. xxxviii., f. 21, p. 237.
Gault. [23485] Folkestone.

Thetironia laevigata (J. Sow.).

H. Woods, Mon. Pal. Soc., 1907, pl. xxvi., figs. 11, 13, p. 169.
Greensand. [19783, 19780] Blackdown.

Thracia carinifera (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1909, pl. xl., f. 12, p. 244.
Chalk Marl. [23500] Chard.

H. Woods, Mon. Pal. Soc., 1909, pl. xl., f. 13, p. 244.
Chalk Marl. [23499] Near Beaminster, Dorset.

Thracia rotundata (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1909, pl. xxxix., f. 10, p. 241.
Lower Greensand. [23470] Lympne.

Thracia sanctaecrucis, Pict. and Camp.

H. Woods, Mon. Pal. Soc., 1909, pl. xl., f. 5, p. 243.
Gault. [23484] Black Ven.

H. Woods, Mon. Pal. Soc., 1909, pl. xl., f. 6, p. 243.
Gault. [1662] Folkestone.

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Thracia sp.

H. Woods, Mon. Pal. Soc., 1909, pl. xl., figs. 7, 8, p. 243.
Gault. [23482, 23483] Black Ven.

H. Woods, Mon. Pal. Soc., 1909, pl. xl., f. 9, p. 243.
Greensand. [19813] Blackdown.

Toucasia lonsdalei (J. de C. Sow.).

H. Woods, Mon. Pal. Soc., 1908, pl. xxxiii., figs. 4, 5, p. 207.
Lower Greensand. [22720, 22721] Stock Orchard, near Calne.

Trigonia affinis, J. Sow.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxii., f. 5, p. 94; 1879, p. 240.
Greensand. [19930] Great Haldon, Devon.

Trigonia aliformis, Park.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxv., figs. 3, 4, p. 116.
Greensand. [19929, 19928; 27006] Blackdown.

Trigonia aliformis, Park., *var.* **attenuata,** Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxv., figs. 5, 6, p. 118.
Upper Greensand. [27007, 27008] Ventnor, Isle of Wight.

Trigonia archiaciana, d'Orb.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxv., f. 10, p. 140; 1877, p. 203.
Upper Greensand. [25393] Undercliff, Isle of Wight.

Trigonia carinata, Agassiz.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxv., f. 3, p. 179.
Upper Greensand. [27082] Ventnor.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxv., figs. 4–6, p. 179.
Lower Greensand (Perna Bed). [27079-27081] Atherfield.

Trigonia caudata, Ag.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxvi., figs. 5–7, p. 129.
Lower Greensand. [27060-27062] Isle of Wight.

Trigonia costigera, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1879, pl. xli., f. 17, p. 205.
Chloritic Marl. [27042] Dunscombe.

Trigonia crenulifera, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xl., f. 9, p. 189. H. Woods, Mon. Pal. Soc., 1900, p. 82.
Chloritic Marl. [27066] Dunscombe.

Trigonia daedalea, Park.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxii., figs. 7, 8; pl. xxiii., figs. 2, 3; pl. xxviii., f. 8, p. 100.
Greensand. [27051-27055] Blackdown.

Trigonia debilis, Lycett.

J. Lycett, Mon. Pal. Soc., 1877, pl. xli., f. 5, p. 189.
Chloritic Marl. [27071] Dunscombe.

Trigonia dunscombensis, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xli., f. 14, p. 188.
Chloritic Marl. [27043] Dunscombe.

H. Woods, Mon. Pal. Soc., 1900, pl. xix., f. 12, p. 78.
Upper Greensand. [6774] Humble Point, Lyme.

Trigonia etheridgei, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxvii., figs. 1–3, p. 127.
Lower Greensand (Perna Bed). [27063-27065] Atherfield.

Trigonia excentrica, Park.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxi., f. 6, p. 94.
Chloritic Marl. [20004] Chardstock.

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Trigonia fittoni, Deshayes.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiii., f. 4, p. 132.
Gault. [27067] Folkestone.

Trigonia ingens, Lycett.

J. Lycett, Mon. Pal. Soc., 1879, pl. xxxvi., figs. 5, 6, p. 207. H. Woods, Mon. Pal. Soc., 1890, p. 75.
Middle Neocomian. [27040, 27041] Tealby, Lincolnshire.

Trigonia meyeri, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiii., f. 6, p. 125.
Chloritic Marl. [25390] Near Sidmouth.

J. Lycett, Mon. Pal. Soc., 1875, p. 125; 1879, pl. xli., figs. 15, 16.
Chloritic Marl. [27068, 27105] Dunscombe.

Trigonia nodosa, J. de C. Sow.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxv., f. 1, p. 106.
Lower Greensand. [27056] Sandown, Isle of Wight.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxv., f. 2, p. 106.
Neocomian. [27057] Tealby.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxxvii., figs. 5, 6, p. 106.
Lower Greensand. [27049, 27050] Atherfield.

Trigonia nodosa, J. de C. Sow., *var.* **orbignyana,** Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiv., figs. 1-3, p. 107. H. Woods, Mon. Pal. Soc., 1909, p. 78.
Lower Greensand. [27047, 27048] Atherfield.

Trigonia ornata, d'Orbigny.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiv., figs. 6, 7, p. 139. H. Woods, Mon. Pal. Soc., 1900, p. 85.
Lower Greensand (Perna Bed). [27069, 27070] Atherfield.

H. Woods, Mon. Pal. Soc., 1900, pl. xix., f. 13, p. 85.
Lower Greensand (Hythe Beds). [6771] Lympne.

Trigonia scabricola, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxvii., figs. 4, 5, p. 130. H. Woods, Mon. Pal. Soc., 1900, p. 82.
Greensand. [27058, 27059] Blackdown.

Trigonia scapha, Ag.

H. Woods, Mon. Pal. Soc., 1900, pl. xx., f. 2, p. 73.
Lower Greensand (Snettisham Clay). [19888] S.W. of Snettisham Church, Norfolk.

Trigonia spectabilis, J. de C. Sow.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxvi., figs. 1-3, p. 112. H. Woods, Mon. Pal. Soc., 1900, p. 80.
Greensand. [27044-27046] Blackdown.

Trigonia spinosa, Parkinson.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiii., f. 10, p. 136. Redescribed as **T. spinosa,** *var.* **subovata,** J. Lycett, Mon. Pal. Soc., 1877, p. 201. **T.**
Upper Greensand. [27072] Isle of Wight.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxviii., figs. 1, 2, p. 136. Redescribed as **T. spinosa,** *var.* **subovata,** J. Lycett, Mon. Pal. Soc., 1877, p. 201. **T.**
Upper Greensand. [27073, 27074] Warminster.

Trigonia upwarensis, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiii., figs. 8, 9, p. 143. H. Woods, Mon. Pal. Soc., 1900, p. 86.
Lower Greensand. [25395, 25396] Upware.

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Trigonia vectiana, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxiv., figs. 10, 11; pl. xxv., f. 7, p. 123.

Lower Greensand (Perna Bed). [27075-27077] Isle of Wight.

Trigonia vicaryana, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1875, pl. xxv., f. 8, p. 141; 1877, p. 203.
H. Woods, Mon. Pal. Soc., 1900, p. 87.

Greensand. [27078] Near Sidmouth.

Unicardium ringmeriense (Mant.).

H. Woods, Mon. Pal. Soc., 1907, pl. xxv., f. 14, p. 164.

Chloritic Marl. [19803] Chardstock.

Unicardium sp.

H. Woods, Mon. Pal. Soc., 1907, pl. xxv., f. 12, p. 163.

Greensand. [G.S. 1580] South Devon.

Velopecten studeri (Pictet and Roux).

H. Woods, Mon. Pal. Soc., 1903, pl. xlii., f. 2, p. 218.

Gault. [1612] Folkestone.

Venus? fenestrata, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. i., 1845, pl. ii., f. 6, p. 240.

Lower Greensand. [2182, 2183] Peasemarsh.

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OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1915.

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FOR

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1915.

I.—*INTRODUCTION.*

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

The field-work during the year 1915 was carried out in England and Wales in the District of Denbighshire and the adjacent counties, and in the District of Warwickshire and Staffordshire. In the Denbighshire district the southern termination of the coal-field has been reached, and progress has been made with the surveying of the older rocks on the one side, and of the Trias on the other. The pre-Cambrian rocks of Haughmond Hill have also been mapped. In the Warwickshire and Staffordshire district the study of the upper red Coal Measures has been continued with important results. In the former county the surveying has been completed as far south as Coventry, and has rendered possible revised estimates of the depth and resources of the concealed coal-field. On the borders of the South Staffordshire Coalfield an area hitherto believed to be overspread by Bunter now appears to be occupied mainly by the red measures, with Bunter sandstone as outliers only. The productive measures may be more accessible than was supposed.

In Scotland progress has been made on several important points bearing on the future developments of the coalfields. The little known and complicated structure of the Carboniferous rocks around Auchterhead Muir (Sheet 23) has been elucidated, and the area now awaits economic development. The boreholes which are being put down to prove the extent and structure of the concealed Coalfield of Central Ayrshire have been investigated.

In addition to the normal field-work an examination was made of the workings for various minerals in England, Wales and Scotland for the purposes of a series of 'Special Reports on the Mineral Resources of Great Britain.' The series was initiated partly on account of a shortage of some materials as a result of the War, and partly with a view to the fuller utilisation of home-sources after the War. The first three volumes were published (see p. 41).

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The results of the year's field-work may be summarised as follows:—

METAMORPHIC AND IGNEOUS ROCKS OF THE HIGHLANDS.

Work was continued in Inverness-shire. On the western margin of the Laggan granite the complex, usually found in such situations, contains altered sediments of pelitic character, and is associated with granite containing abundant biotite. Siliceous schists on the opposite margin are associated with highly acid granite.

PRE-CAMBRIAN ROCKS.

The Longmyndian rocks of Haughmond Hill have been surveyed, and a sequence, in what is believed to be descending order, determined.

CAMBRIAN.

Fossils have been collected from the Cambrian Rocks of Shropshire under the guidance of Prof. Lapworth, and are undergoing examination by him (see p. 38).

ORDOVICIAN.

Good progress has been made in the surveying of the Bala and Llandilo Beds of the neighbourhoods of Llanrhaiadr and Llanfyllin, and of the igneous rocks intruded into them. Some beds of ash, which give a key to the structure, have been traced out in detail. The difference in the faunas of the upper and lower parts of the Bala Series seems sufficient to justify the separation of the two parts under different names. It is believed that the limits of the 'Ashgillian,' as defined by Dr. Marr,[1] are recognisable in North Wales. The term therefore is provisionally adopted, and the Bala Series accordingly is divided into Ashgillian above and Caradocian below.

Fossils have been collected from the Ordovician rocks of Shropshire for examination by Prof. Lapworth (see p. 38).

CARBONIFEROUS.

The Carboniferous Limestone thins away southwards towards its termination in Shropshire, but somewhat irregularly, owing to the inequalities in the surface of Lower Palæozoic rocks upon which it rests. The uppermost beds are assignable to the Dibunophyllum zone, but the zonal position of the lower beds is still in doubt. The Millstone Grit preserves the same general characters and relations to the limestone as in the district farther north.

Coal-mining has long been discontinued in the part of Shropshire surveyed during the year. Red marls and sandstones with a Spirorbis-limestone, which lie on the north-east side of Haughmond Hill, are attributable to Keele Beds. They are overlain by conglomerates which correspond to the Hamstead Beds of South Staffordshire.

In Staffordshire the red measures have been found to occupy an area which was believed to be overspread by Bunter. The depth to the productive measures can be estimated under such circumstances and is not excessive.

[1] *Quart. Journ. Geol. Soc.*, vol. lxxi (1915), p. 189.

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In Ayrshire the revision of the Calciferous Sandstone Series with its interbedded ashes and mugearitic lavas, and of the Limestone Series and Coal Measures, has been continued. In Lanarkshire much light is being thrown on the structure of an obscure area near the northern margin of Sheet 23 by the study of a number of boreholes recently put down by the Coltness Iron Company, and kindly communicated to the Geological Survey. An area of Coal Measures on the eastern margin of the Wishaw Coalfield has been revised. Lavas and ashes near Strathaven have been examined, and some 'greenstones,' formerly supposed to be intrusive in Lower Old Red Sandstone, are now believed to be lavas of Calciferous Sandstone age.

TRIAS.

In parts of Shropshire all the subdivisions of the Keuper and the Bunter are recognisable, but the precise separation of the two formations is impossible. The base of the Keuper lies somewhere within a mass of freestone, all of which is quarried, but which becomes gradually softer downwards.

In the part of Staffordshire surveyed during the year the Bunter is not fully developed, but each of the subdivisions of the Keuper forms a broad outcrop. The Rhætic Beds are nowhere now visible in the area recently surveyed.

JURASSIC.

The Lower Lias has been examined in the cement works near Newbold-on-Avon and other places. In Scotland, near Tobermory, basaltic lava-flows, resting on Triassic or Jurassic rocks, have been surveyed, and the results of the late Prof. Judd's mapping confirmed.

GLACIAL.

The Drifts connected with a south-eastward glaciation within the borders of Wales have been examined, and some notable boulders traced to their source in Wales. The ice crossed the high Carboniferous ground, and even in the low ground near Shrawardine brought Welsh detritus mainly. Farther to the north-east, however, boulders of northern origin appear. The two distributions are separated by a belt of drift-sand with a characteristic moundy form. Late Glacial flood-gravels are a notable feature in the district near Oswestry.

On the eastern side of the Warwickshire coalfield brown clays and flint-gravels reach a thickness of 200 feet, and part of the Avon valley-system has been excavated wholly in glacial drift. On the western side the thickness is less and the drift has been derived from a different source; flints are absent, and Bunter pebbles form the preponderance of the boulders. In Staffordshire drift derived from western sources has, so far, alone been met with. In some otherwise driftless areas isolated mounds of sand are conspicuous. Boulders from Welsh sources, with some from Scotland and the Lake District, occur in the drift exposed in new railway-cuttings near Kingswinford.

In Scotland an interesting example of an overflow in glacial times of the waters of the upper part of Glen Spean through Strath Mashie to the Spey has been investigated.

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ENGLAND AND WALES.

Denbighshire and Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.

C. B. Wedd, B.A.
B. Smith, M.A.
C. E. N. Bromehead, B.A.
D. A. Wray, B.Sc.
} Geologists.

During the past season the mapping of the Oswestry Sheet (137) has been completed, with the exception of an area of Lower Palæozoic rocks around Llanfyllin. Mr. Wedd has carried the mapping of the Denbighshire coalfield southward to its termination at Sweeney Mountain near Oswestry, and that of the Carboniferous Limestone to its limit at Llanymynech. Mr. Smith has completed the examination of the Lower Palæozoic rocks near Llansilin, and has advanced southward into the Vyrnwy Valley between Llanfechain and Llanymynech; while Mr. Wray has finished the surveying of the Triassic formations on the south-eastern margin of the map.

In the Shropshire region included in the Wem Sheet (138) Mr. Wray has mapped the Triassic escarpments between Ruyton-Eleven-Towns and Great Ness. Farther east, Messrs. Cantrill and Bromehead have advanced along the southern margin of the map from Hadnall to the valley of the Tern at Waters Upton. In the Shrewsbury Sheet (152) the surveying of the Pre-Cambrian rocks of Haughmond Hill has been completed by Mr. Cantrill.

PRE-CAMBRIAN.

The Longmyndian rocks of Haughmond Hill present the following sequence from east to west, in what is presumably the descending order:—

	ft.
Green Sandstone Series.—Greyish green micaceous sandstones and shales with purple shale and 200 feet of purple sandstones, passing downward. Thickness exposed, about	5,000
Purple Conglomerate.—The fragments chiefly of purple igneous rocks	260
Castle Sandstones.—Purple-grey sandstones with occasional bands of purple shales	650
Abbey Conglomerates.—Purple grits and conglomerates with subordinate purple and lavender-coloured sandstone. Pebbles chiefly of quartzite. Base not seen	1,400

Several diabase dikes cut through the Green Sandstone Series; but, as pointed out by Callaway, the rock shown on the old map (61 N.W.) as a sill following the strike along the centre of the hill is the Purple Conglomerate.

ORDOVICIAN.

In the ground surveyed by Mr. Smith the lenticular sandstones occurring sporadically in the shales above the horizon of the Mynydd-Tarw Ash[1], near Llanrhaiadr, assume greater importance in the Llansilin district. Near Moel-y-gwelltyn they occur in

[1] Summary of Progress for 1914 (*Mem. Geol. Surv.*), p. 7.

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clustered lenticles; in Gyrn Moelfre they form a large part of the mountain and its southern foothills; and in the landslip scar of Craig-Gamhyll can be seen to be over 100 feet thick. The sandstones form the southern limb of an anticline, the northern limb being represented by the equivalent sandstones of Craig-yr-hwch, Foel-Rhiwlas, and Foel-Wylfa.[1] Fossiliferous sandstones higher up in the Llandilo may represent the grit observed by Mr. King in the northern limb of the Berwyn anticline.

The southern outcrop of the Cwm-Clwyd Ash has been traced eastwards from Craig-Orllwyn, through Parc-Sycharth to Coed-Cochion. On the west, at Craig-Orllwyn, it is faulted nearly a mile southward to some position beneath the Tanat alluvium, under which it probably thins out. At Craig-Fawr it forms a faulted syncline, now mapped for the first time; near Priddbwll the southern limb is reversed. A fault throws the outcrop nearly 1½ miles south-south-east of Priddbwll, and the ash is thickened by the addition of an upper series of beds. The outcrop in Coed-Cochion is a recent discovery.

The ash, which is of rhyolitic type, comprising material ranging from fine banded tuffs to crystal-tuffs and agglomerate, includes in its lower parts some interstratified bands of shale. Here and there it encloses bombs (keratophyre, etc.) and twisted and angular lumps of shale. In places the ash is cleaved.

Above the ash, cleaved shales pass upwards into the fossiliferous Bala beds typically developed south of the Tanat Valley. The Bala Series is divisible into an upper stage to which the term Ashgillian seems likely to be applicable, and a lower stage distinguished as Caradocian. The phosphate-bed, has been shown by further investigations, in which Mr. E. D. Nicholson, of Llynclys, participated, to occupy a definite horizon in the Bala at the base of the black graptolitic shales characterised by *Mesograptus multidens*. Its appearance at the base of the Ashgillian in the Llanfyllin district[2] is probably a coincidence, for the Ashgillian rest unconformably upon the Caradocian Beds, and in other places are separated from the phosphate-bed by graptolitic shales.

Ashgillian beds, in synclinal form, occur near Ty-isaf-mawr, north of Llansantffraid, and recent work has shown that the graptolitic shales, calcareous shales, and mudstones, near Glan-yr-afon,[3] are of Ashgillian age.

Throughout the whole of the area described above the strike of the cleavage is usually within a few degrees of east and west; and the dip generally towards the north. South of the Tanat Valley subsequent folding has affected the direction and dip of the cleavage. The intrusion between Bryn and Graig-wen may be described as a plug or laccolite with irregular sill-like offshoots. In the south the igneous rock has apparently risen through the ash of Parc-Sycharth, several patches of which it bears upon its surface. Farther north the sill-like offshoot has insinuated itself between the ash and the underlying shale, whilst still farther north it lies some distance below the ash. Where the mass is thickest its plane of contact with the shales is apparently steep. The intrusion preceded the development of cleavage.

[1] Summary of Progress for 1914 (*Mem. Geol. Surv.*), p. 7.
[2] *Ibid.* [3] *Ibid.*

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The rock is traversed by a thin platy structure, which in places becomes coarse and columnar. The plates, which are always highly inclined, are usually directed radially from the centre towards the margin of the intrusion, and may be attributed to cooling.

In the main intrusion the formation of the platy structure was succeeded by a sheet-brecciation, which crosses the platy structure in planes one above the other and dips at low angles, apparently towards the centre. The brecciation may have been caused by shrinkage setting up shear-strains at a late stage in the cooling-process.

In general the rock is of a fine-grained diabasic appearance, to which the ferro-magnesian mineral occasionally gives a minutely porphyritic structure. On microscopic evidence it may be classed as an albite-augite-porphyrite.

Mr. Wedd finds that, west of Selattyn, the Cwm-Clwyd Ash of Cefn-côch abuts against the Carboniferous Limestone, apparently with a faulted junction, farther south than is indicated on the old map (74 S.E.).

In Coed-Cochion another outcrop, not shown on the old map, makes a small outlier at the ancient fort at Coed-y-gaer, the ash being immediately faulted in again on the south.

A volcanic ash at the Llanddu quarries, near Blodwell Hall, differs from the pink felspathic ash of Cefn-côch and Coed-Cochion in being uniformly fine-grained and dark-grey.

Carboniferous.

Carboniferous Limestone Series.

Mr. Wedd finds that, southward from the Dee Valley, the Carboniferous Limestone below the sandy passage-beds thins away to about 50 feet against Lower Palæozoic rocks north of Llawnt, but increases again southwards to at least 380 feet at Porth-y-waen and Llanymynech Hill. The whole series may be classified as follows: the thicknesses are approximate.

Carboniferous Limestone Series near Oswestry.

(*e*) Calcareous sandstones and sandy limestones, more or less pebbly, weathering to red sandstones, with stained purple shales containing *Syringopora, etc.* Thickness, 200 ft.	Sandy Limestone or Passage-beds.
(*d*) Grey limestones with intercalated shales; one or more coral-beds always present; *Lithostrotion* spp., *Dibunophyllum, Caninia, Cyathophyllum, Lonsdalia floriformis, Productus giganteus.* Thickness, 120 ft.	Upper Grey Limestone.
(*c*) Pale rubbly limestones, calcareous marls and shales, usually purple or crimson; *Lithostrotion, Dibunophyllum* and *Cyathophyllum.* Thickness, 30 ft.	
(*b*) Dark-grey, brown, pinkish, or yellow limestones, some parts oolitic; in places a band of red or crimson shale about 30 ft. below the top, and below the shale smooth porcellanous limestones ('flummery'). About 170 feet.	
(*a*) Shale and calcareous marl, grey, purple, red and yellow, with one or more bands of limestone near the top; Productid and Rhynchonellid brachiopods in upper part. At least 60 ft.	

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Palæontologically *c* and *d* belong to the Floriformis sub-zone (D_2) of the Dibunophyllum Zone; but the evidence is so far insufficient to determine the lower limit of this sub-zone and the zonal value of the lower beds. The thickness of the series here still falls far short of the development in neighbouring districts to the north, where no definite evidence was found of any horizon below the Dibunophyllum Zone.

The basal shales (*a*), local to the southern end of this district, appear at the large Nant-mawr quarry, and in old mining galleries and shafts under Llanymynech Hill. Their top has been opened to view recently at Whitehaven and Porth-y-waen.

In the lower part of group *b* rough-textured and porcellanous limestones are best seen in a disused quarry at Nant-mawr. They resemble the Lower Grey Limestone of the Llangollen district, but have not yielded the same fauna; they may be contemporaneous with some part of the White Limestone of that district.

The overlying rubbly limestones (*c*) mark a continuous horizon, probably throughout, and certainly from Nant-mawr southward. They are well seen at the top of the Nant-mawr quarry, on the southern side of the Porth-y-waen gap and along the eastern side of the mass of Llanymynech Hill, where they constitute the highest horizon that crops out from beneath the valley-gravels.

The group *d* represents the upper part of, if not all, the Upper Grey Limestone of the northern outcrop. But its lowest beds throughout this district, and apparently the highest beds also in the southern part, usually consist of pale-grey crystalline limestone. The rest is thin-bedded dark and lighter grey limestone with beds of shale, and one or more strongly coralliferous horizons. At Little Nuttree Bank the highest beds are rather arenaceous, and one bed contains scattered quartz-pebbles.

From Nant-mawr southward secondary dolomitization has affected the limestone. It is most complete and extensive in the limestone of *b* on the northern side of the Porth-y-waen gap.

The sandy limestones, hard calcareous sandstones and brown decalcified sandstones of the Sandy Limestone group at Llawnt begin, at Croesau-bâch, north of Mynydd-Myfyr, to pass southward into decalcified bright-red sandstones (*e*). Decalcification and red staining distinguish this group to the margin of the Bunter sandstone north of Llynclys. But the staining is less complete and regular near the Bunter outcrop, perhaps owing to inequality of post-Triassic denudation. Morton wrongly, as it seems, regarded these red sandstones as equivalent to the 'Lower Sandstones and Conglomerates' of Ruabon Mountain.

CEFN-Y-FEDW SANDSTONE ('MILLSTONE GRIT').

The upward passage into the Cefn-y-fedw Sandstone is gradual. The general sequence is similar to that given in 'Summary of Progress' for 1914, p. 10. Cherty Beds—fine-grained silty sandstones of 'china-stone' aspect, often full of brachiopods—and chert-bearing sandstones, constitute a readily recognizable horizon.

Some distance higher a coal 1 ft. 6 in. thick, with underclay, is traceable from Trefonen to the Oswestry road at Underhill; and is succeeded by quartzose sandstones with pebbly seams, exposed only near Trefonen.

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COAL MEASURES.

There are no exposures of the Coal Measures in the Oswestry district, and mining has long since been discontinued. Until the examination of old plans is completed, it is impossible to compare this area with the rest of the coalfield.

North-east of Haughmond Hill the red sandstones and marls coloured as Permian on the old maps (61 N.W. and 73 S.W.) are exposed in the valley of the Roden between Roden village and Great Wytheford, and also around Walton, near High Ercall. Mr. Cantrill finds that the lower beds consist of bright-red marls, with red and lavender-coloured sandstones, in which a band of Spirorbis limestone crops out in Ercall Park. These lower beds are succeeded by purplish-red sandstones and bright-red marls, in which two beds of conglomerate have been traced at Walton. The conglomerates consist of well-rounded pebbles of quartzite, sandstone, and Carboniferous Limestone chert, in a sandy and calcareous matrix. The beds below the conglomerates can be correlated with the Keele Beds; but no evidence has been obtained that the conglomerates and their associated sandstones and marls, which evidently correspond to the Hamstead Beds of South Staffordshire, belong to the true Permian.

At the north-eastern extremity of this tract of Keele Beds Mr. Bromehead finds that red marls are exposed near Muckleton; but the faults that presumably bound the outcrop on both sides are concealed by drift.

TRIAS.

It was suspected that the Bunter Sandstone south of Oswestry (Summary for 1914, p. 12) gave rise to certain drift-covered ridges, one of which runs north-north-east from Llynclys Station; but no actual evidence was found.

At the suggestion of Mr. E. D. Nicholson, of Whitehaven, Llynclys, Mr. Macdonald, Chief Engineer of the Cambrian Railway Company, kindly had a small opening made for Mr. Wedd's inspection in the railway-cutting about 130 yards north of the bridge at Llynclys Station. This opening showed at the bottom of the cutting 2 feet of red sandstone, streaked with buff, precisely similar to that of the sand-pit north of Llynclys and to that which overlies the purple Upper Coal Measure marls at Weston Lower Mill.

This further evidence suggests that the Triassic overstep reaches a horizon below the top of the main Carboniferous Limestone.

In the district surveyed by Mr. Wray around Ruyton-Eleven-Towns and Great Ness further exposures of the Upper Mottled Sandstone have been examined around Kinton, Kynaston, Nesscliff and Ruyton. The rock in a faulted outcrop shown as Pebble Beds on the old map (74 S.E.) is exposed at Kinton. It consists of soft bright-red sandstone devoid of pebbles, and is more likely to belong to the Upper Mottled Sandstone, a conclusion in harmony with the known range of the Pebble Beds at Kinnerley on the west and of the Keuper at Nesscliff on the east. No evidence of the supposed faulting has been obtained.

The difficulty experienced farther north, at Haughton and Tedsmore, in distinguishing the uppermost beds of the Bunter

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from the lowest sandstones of the Keuper has been found to be equally great about Ruyton and Nesscliff, the one passing imperceptibly up into the other. This passage is well shown at Nesscliff by a deep quarry in which the lowest beds, though hard enough to have been worked for building-stone, appear by their deep red colour to belong to the Bunter, while the higher beds, which are slightly harder and less brightly coloured, are presumably Keuper. The Keuper Basement Beds, together with a small thickness of the Upper Mottled Sandstone, are thus represented by an indivisible mass of sandstone. The mass has a thickness of about 120 feet, and is worked as a freestone in a series of deep quarries. It forms a well-marked escarpment, the base of which affords a guide for dividing the building-stones from the soft sandstones of the Bunter.

Clearly the conditions obtaining in this part of Shropshire at the close of the Bunter period differed from those prevailing in Cheshire on the one side and in South Shropshire, Staffordshire and Worcestershire on the other, where a sharp line accompanied by local erosion and a distinct lithological change marks the base of the Keuper. Deposition appears to have been more continuous towards the deeper part of the basin.

The Waterstones, into which the sandstone above described passes upward, consist of about 120 feet of chocolate-coloured flaggy sandstones and red and grey sandy shales. The sandstones show numerous minute drusy cavities. The Keuper Marl consists of the usual deep chocolate-coloured marl with thin bands of sandstone.

In last year's Summary (p. 14) it was suggested that the Prees syncline extends south-westward to the neighbourhood of Haughton and Ruyton, and the mapping of the Triassic outcrop still farther south has tended to confirm this view.

The Bunter outcrop forms the rim of a broad basin, within which the outcrop of the Lower Keuper Sandstone forms a parallel band. This is traceable as far south as Ellesmere, but is there lost under thick drift. To the south-west the outcrop can be followed as far as Great Ness, where it turns north-eastward to Little Ness. Still farther within the basin the Keuper Marls may be assumed to underlie the drift at and north of Baschurch, and to continue eastward under the drift much farther than was supposed. The basin is complicated by considerable faulting.

The Bunter sandstone represented on the old map (61 N.W.) as lying along the northern side of the 'Permian' rocks near Shrewsbury, is generally covered with drift, but has been reached in a deep well near Hadnall at a depth of 145 feet. Mr. Cantrill finds that the rock emerges from below the boulder-clay at Astley, where it consists of false-bedded bright-red sandstone, soft, and devoid of pebbles. This may be referable to the Upper Mottled Sandstone.

To the north of Hadnall, in ground mapped by Mr. Bromehead, what is believed to be the Upper Mottled Sandstone appears here and there from beneath a cover of boulder-clay.

Between Shawbury and the Tern at Waters Upton, the solid rock appears to belong to the Lower Mottled Sandstone, presumably faulted against the Upper Mottled Sandstone on the west. In the most westerly exposure, at Edgebolton, the rock forms a prominent

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knoll overlooking the Roden on the north but disappearing gradually beneath the drift in other directions. Towards Ellerdine, Rowton and Cold Hatton the Lower Mottled Sandstone reaches the surface over a considerable area.

The Bunter Sandstone lying south-east of the 'Permian' tract and exposed at High Ercall and thence towards Crudgington, appears to belong to the Lower Mottled Sandstone, as Mr. Cantrill finds that it is overlain west of the last-named place by Pebble Beds.

Farther north, Mr. Bromehead notes that the Pebble Beds are well developed on the east of the Tern, and are sharply divided from the Lower Mottled Sandstone. At Waters Upton, where they are exposed for at least 40 feet, the lower part contains many pebbles up to six inches in diameter, together with small fragments which are usually angular. The upper part contains scattered stones only, and forms a good building-stone, from which the church at Waters Upton and the bridges on the Wellington and Market Drayton Railway were constructed.

A coarse-grained white or buff sandstone of somewhat saccharoidal texture, which was quarried many years ago between Muckleton and Ellerdine, may belong to the Pebble Beds, but its relationship to other outcrops is obscure.

GLACIAL.

In the Llansilin district, mapped by Mr. Smith, the boulder-clay, like that of the Tanat Valley area, has been derived solely from the Welsh hills. Amongst the boulders are some of spherulitic rhyolite, and a mass of Llandilo limestone, broken into six fragments of a total volume of over 1,700 cubic feet, was discovered 550 yards south-west of Llansilin Church. Its probable source is Craig-y-Glyn, 5 miles to the west. The northern slopes of Gyrn-Moelfre mark the southern limits of distribution of boulders of Berwyn dolerite. No Arenig boulders have been found.

Glacial striae, smoothed rock-surfaces and disturbed strata, occurring on the highest elevations, show that the general movement of the ice, when at a maximum, was south-easterly.

The boulder-clay of the Vyrnwy Valley is similar to that of the Llansilin district, but certain boulders found north of the Tanat do not occur here.

A dry glacial channel, trending from west to east, has been noted between Lloran-ganol and Mynydd-y-Briw. A finer example, between Plâs-gwyn and Glascoed, crosses the watershed between the Vyrnwy and Tanat as a flat-bottomed trench, reaching 100 feet in depth, and opens upon the terrace of Late-Glacial gravel near Glascoed. At the intake there are fluvio-glacial gravels.

Mr. Wedd finds evidence that the Welsh ice covered the high Carboniferous ground, and that most of the hollows contain Welsh boulder-clay up to an altitude of 900 feet.

The gentler slopes down to the highest river-gravels are almost entirely covered with this boulder-clay, often more or less gravelly. In the grounds of Llanforda Hall a terrace-like spread of stratified slate-gravel runs along the northern brow of the Morda Valley at

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an altitude of 600 feet, and more than 200 feet higher than the fluvio-glacial gravels of the river-valleys.

In the south of the district the glacial striae range between E. 35° S. and N. 15° E., the direction of ice-flow being eastward down the river valley, with a tendency to northward deflection in overriding the high ground north of the valley.

On the lower slopes bordering the Severn and Vyrnwy valleys between Kinnerley and Shrawardine Mr. Wray finds that the drift is composed mainly of Welsh detritus. Farther to the north-east, however, some Chalk flints and granite-boulders, derived from northern sources, appear. Between the two districts a broad belt of sand and gravel of characteristic mounds form intervenes.

Mr. Cantrill finds that, north of Shrewsbury, red loamy boulder-clay covers the Trias about Albrighton and Battlefield. It contains abundant fragments of Keuper Marl skerry, and thus supports the contention (p. 9) that much of the drift-covered ground east of Ruyton is occupied by Keuper Marl and not by Bunter Sandstones. In addition to skerry, pebbles of Lower Palæozoic rocks of Welsh derivation are abundant, together with occasional pebbles of Carboniferous limestone and sandstone, and boulders of granite. The same red boulder-clay extends eastward of Astley, through Roden and south of High Ercall, towards Longdon-upon-Tern.

Overlying and intercalated in the boulder-clay lenticular masses and thin sheets of gravel and sand have been mapped between Astley and High Ercall. They contain a large proportion of red Triassic sand, with a few pebbles from the Millstone Grit. No materials from the Lias of Prees have yet been noticed in any of the drifts, though Chalk-flints occur in the gravels.

Farther north, Mr. Bromehead finds that the drift about Hadnall and Shawbury is mainly of Triassic origin, but contains boulders of granite and felsite with some fragments of Welsh rocks in the gravels. Small patches of Trias appear from beneath the mantle of drift, which, judging from the depths of the wells, is nowhere thick.

From the neighbourhood of Ellerdine Heath a long narrow strip of boulder-clay stretches south-eastwards to Sitch Lane, where it is cut across by the valley of the Tern. It probably occupies a pre-Glacial valley, independent of and cut obliquely by the present drainage.

Late-Glacial, Post-Glacial and Recent.

The Late-Glacial flood-gravels along the lower reaches of the Morda, Vyrnwy and Severn valleys have now been traced onto the margin of the Shropshire plain.

Mr. Wedd finds that the gravel of the broad flat south of Oswestry, though broken up by islands of Glacial drift and Triassic sandstone, is continuous with the highest terrace of the Vyrnwy and Tanat valleys.

The terrace of Late-Glacial flood-gravel[1] bordering the Tanat is found by Mr. Smith to have its counterpart in that of the Vyrnwy valley, which sometimes rises in bluffs from 30–40 feet above the

[1] 'Summary of Progress for 1914,' p. 17.

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alluvium. West of Llansantffraid, where the valley is constricted, these gravels form a true kettle-drift.

In the valleys the gravels are heterogeneous deposits, rudely stratified; but where the Vyrnwy debouches onto the plain, near Llanymynech, gravel is spread out as a broad outwash-fan, sloping towards the south-east and decreasing in both thickness and grade of material.

This fan overlies a second fan, of clay with very small stones, which forms a large area of pasture-land between the alluvium of the Vyrnwy and that of the Severn. Hollows and ridges, apparently of original deposition, in both gravel and clay, trend south-eastwards. Islands of boulder-clay rise occasionally from beneath the fan.

Farther to the east these Late-Glacial flood-gravels have been found by Mr. Wray to lose themselves among the low mounds of drift around Kinnerley, Edgerley and Wilcott; and where the Severn valley reaches Shrawardine they are no longer recognizable.

Terraces have been cut at a later date in these deposits. The recent alluvium of the Vyrnwy and Severn is a brown loam with few stones. On the plain it rests sometimes upon gravel, sometimes on the Late-Glacial clay.

Several landslips have occurred in the Llansilin district since Glacial times. In one case a large mass of ash has broken away from the crag in Parc-Sycharth, whilst falls of sandstone have been noticed near Moelfre. The greatest of these fell from Gyrn-Moelfre and gave rise to Llyn-Moelfre—a good example of a lake dammed by a landslip.

Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.

E. E. L. Dixon, B.Sc., A.R.C.S.
R. L. Sherlock, D.Sc., A.R.C.S.
H. Dewey.
T. Eastwood, A.R.C.S.
} Geologists.

The field-work during the year consisted in the completion of the survey of the country contiguous to the Warwickshire Coalfield in Sheets 168 and 169; and in the continuation of the survey in Sheets 153 and 167, which include the ground lying west of the South Staffordshire Coalfield.

Coal Measures.

South Staffordshire Coalfield.—In the Summary for 1911 (p. 23) it was mentioned that the country bordering the South Staffordshire Coalfield, on its west side, between Littleton Colliery, Huntington (on the north) and Holly Bank Colliery, Essington (in the south) had been proved by mining to consist of a belt of disturbed ground, from one to two miles in width.

Within this tract the rocks at the surface have hitherto been considered to belong entirely to the Triassic formation; but Mr. Dixon finds that, in the districts of Saredon and Shareshill, north of Essington, they consist of high Coal Measures supporting small outliers only of Bunter Sandstone. An area of at least four square

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miles is thus added to the exposed coalfield. It appears that under it all the workable seams as proved at Holly Bank Colliery and Littleton Colliery should be accessible at depths between 2,000 and 2,600 feet by shafts commencing in Coal Measures.

The Triassic outliers occur in rows, of which one ranges from near Cheslyn Hay southwards towards Essington; while another parallel line extends from Great Saredon to Featherstone. Sections showing the character of the Carboniferous rocks in the intervening ground are few and obscure. That the rocks at the surface are Upper and not Middle Coal Measures is shown by their composition and the structure of the proved coalfield lying immediately to the east. It is certain that the Etruria Marls are at the surface up to the fault proved in the eight-feet seam near Holly Bush Hall, south-west of Cheslyn Hay; but to the west of this fault the sections are not sufficiently clear to prove whether this group of the Upper Coal Measures, or, as is more probable, the Keele Beds are at the surface. If the two large faults, with an aggregate down-throw west of 470 yards in the workings of Holly Bank Colliery along the eastern edge of Hilton Park, extend northward, the Keele Beds should underlie the outliers of Bunter at Saredon and Shareshill. A thickness of about 900 feet of Keele Beds may be estimated to overlie the faults at Hilton Park.

On the line of strike going north towards Laney Green, the surface of the ground falls 200 feet, so that in this locality, about 700 feet of Keele Beds may be present. Possibly, the two down-throw faults increase their throw northwards, though this is contrary to the evidence of the Ashmore Park Colliery, where the vertical displacement is much greater than at Holly Bank. Even if they do increase northwards their united throw would still be insufficient to bring in the higher conglomeratic bands of the Keele Group, of which there are no traces over the low ground about Laney Green; though at Shareshill, half-a-mile to the south-west, in the direction of full dip, material resembling these beds was thrown out in excavating an old sewer along the side of the road going north from the village. At Laney Green, a liberal estimate would give a thickness of 1,700 feet for the Upper Coal Measures, including 700 feet of Keele Beds and a thickness of not more than 900 feet for the Middle Coal Measures down to the Deep (Bottom) Coal, thus giving a depth of 2,600 feet for this, the lowest workable coal, and a less depth to many other valuable seams which may be expected to occur.

EXTENSIONS OF THE WARWICKSHIRE COALFIELD.

Now that the survey of the Warwickshire Coalfield and the adjacent country has been completed to the southern margin of Sheets 168 and 169, and all the available information relating to the area has been collected, the results bearing on the extension of the coalfield can be summarised. The Reports of the Royal Commission on Coal Supplies for 1905 will be taken as a basis for comparison.

(1) *Eastern extension.*—On p. 11, Appendix No. 1 of the Final Report, it is stated that " It may be that workable Coal Measures exist along some parts of the Hinckley synclinal, but as yet it is unsafe to speculate either as to their probable position or their

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possible coal resources." The supposed existence of Coal Measures is based on the borings of Sapcote Freeholt (sometimes referred to as the Elmsthorpe boring) and of Brandon, in neither of which are the records sufficiently detailed as regards the part ascribed to the Coal Measures. Disturbances met with at Binley Colliery, 3 miles S.E. of Coventry, suggest that the Coal Measures may turn over to the east and that they may have been found in the Brandon boring as recorded; but any considerable extension of the coalfield to the east must still be regarded as highly problematical.

(2) *Central extension.*—West of the visible coalfield an area of about 70 square miles is occupied by the so-called Permian Rocks, which extend from their outcrop in the east to the Western Boundary Fault between Berkswell and Kingsbury.

A portion extending over 32 square miles, situated between the outcrop in the east and an arbitrary straight line drawn from Wyken through Arley to near Kingsbury, was included in the estimates of the 1905 Report. Under the remainder it was considered (Pt. iii., p. 7) that some of the Warwickshire coals no doubt extended "but to what extent is unknown." The survey of the ground by Mr. C. H. Cunnington and Mr. T. Eastwood, and the information obtained from the recent borings (see Summary for 1914, pp. 29-23) at Whitmore Park and Keresley, together with the examination by Mr. Cunnington of the cores of the older Packington boring, show that the excluded area of 38 square miles can now be included in the estimates.

The age, composition and thickness of the so-called Permian rocks have been dealt with in previous Summaries (1913-14), so that it is only necessary to deal here with the probable depths to the seams of coal. South of a line drawn from Wyken through Whitmore Park to the Western Boundary Fault near Meriden, the Warwickshire coals should lie between 2,500 and 3,000 feet from the surface: north of this line, below an area of about 20 square miles, the seams should be found between 2,000 and 2,500 feet from the surface.

Western Extension.—The Warwickshire Coalfield consists of a broad syncline with its centre near Tile Hill. Along the western limb of the fold the Keele Beds rise somewhat rapidly to the west and so bring their lower sandstones and marls with the Spirorbis limestones against the Western Boundary Fault between Meriden and Nether Whitacre; but at present there are no data for estimating either the throw of the fault or the thickness of the Trias, except that of the Keuper Marl between Barston and Coleshill, which is not less than 700 feet.

TRIAS.

The country lying west of the South Staffordshire Coalfield is occupied by Triassic rocks. From them Wolverhampton obtains its water, and sites for additional supplies as well as for other districts in South Staffordshire have been selected recently within the area under survey

The existence of Lower Mottled Sandstone is doubtful in this area and the Pebble Beds are confined to the outliers previously mentioned (p. 13); while the Upper Mottled Sandstone occurs

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with certainty only in the south. All the three sub-divisions of the Keuper are represented, the Lower Keuper Sandstones and Waterstones both forming broad outcrops.

BUNTER.

A brick-red sandstone coming out from under the outlier of Pebble Beds at Great Saredon may represent a local development of the Lower Mottled Sandstone. The Pebble Beds do not appear to exceed a thickness of 100 feet in any of the outliers between Saredon and Essington, and are poorly exposed. Between Bednall in the north and Featherstone in the south, according to Mr. Dixon and Dr. Sherlock, no Upper Mottled Sandstone is recognisable, but it appears from under the Lower Keuper Sandstone between Wolverhampton and Albrighton. At Tettenhall Waterworks it is over 500 feet thick.

It is worked for moulding-sand and frequently exposed on the west side of the Tettenhall gap. The sand is dug out in steps to a depth of about 40 feet, and, in spite of its softness, remains standing as vertical walls in the disused pits. The upper part of the subdivision between Perton and Pattingham has been indurated into a fine-grained fissile stone which was quarried for re-building St. Peter's Church, Wolverhampton. Some further notes on the Bunter Sandstone exposed in new railway-cuttings will be found on p. 17.

KEUPER.

The Lower Keuper Sandstone consists of massive light-red and yellow building-stones with coarse and pebbly sandstones and bands of calcareous conglomerates at or near their base. The sequence thus resembles that of Wirrall (Summary for 1912, p. 17), but differs from that of the intervening area of Ruyton (*see* above, p. 9).

Southwards the outcrop, often concealed beneath Drift, gradually approaches that of the Bunter, leaving only a narrow strip for the Upper Mottled Sandstone between Bednall and Saredon. South of Saredon, near Featherstone, Dr. Sherlock notices that the conglomeratic basal bed, whether by overlap or fault, comes into close proximity to the Upper Coal Measures. The building-stones are quarried around Penkridge, and were formerly much worked farther south, near Brewood. At Kingswood a yellow stone, and at Codsall a brown stone, are obtained. To the south and west of Codsall and around Tettenhall the coarse sandstones form conspicuous features. At their base a calcareous conglomerate, containing pebbles of Carboniferous Limestone, graduates into pebbly sandstone and grit.

The building-stones pass upwards into the Waterstones by the gradual incoming of marls and siltstones, in which *Estheria minuta* was found by Mr. Dewey.

These passage-beds occupy wide tracts west of Brewood and between Codsall and Albrighton. The presence of the Waterstones west of Brewood may be due to an anticline, for between Codsall and Albrighton Mr. Dewey notes some unusually sharp folds ranging towards Brewood.

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LIAS.

In continuing the survey along the southern margin of Sheet 169 (Coventry) Mr. Eastwood finds the Lower Lias, cropping out from under the Drift, in the low ground along the Avon and its tributaries south of Harborough Magna and Churchover. Sections are rare. In the northern pit of the Portland Cement Company near Newbold-on-Avon, the Cement Stone group is quarried to a depth of 80 feet. The proportion of clay to limestone is about three to one. Similar strata are seen in the disused cement-stone workings of King's Newnham, and by the old canal near Newbold Lodge.

In the small outlier of the Cement-Stone group at Copt Heath (Sheet 168) and Knowle (Sheet 183) the structure is evidently not so simple as hitherto assumed. Commercially the area is of small value.

GLACIAL.

Warwickshire.—East of the Warwickshire Coalfield and south of the main watershed which crosses the map (Sheet 169), north of Shilton and Willey, Mr. Eastwood finds that bedded, silty, brown clays and flint gravels, having a united thickness of 200 feet, have been traversed in a boring at Cloudsley Farm. The clays occupy the high ground of the watershed; the gravels appear in the valleys. Traced southwards the silty clays become more sandy and the drifts consist of sands with beds of gravel and clay. The sides of the valleys of the Avon and of the lower reaches of the Swift and Smite, nearly down to the modern alluvia, are composed of glacial material, the excavation having been mainly, if not entirely, post-glacial.

The water supply of the villages and estates is obtained from the sands and gravels; but water, generally sufficient for farm-houses, is also yielded by the silty clays. The water taken from the Glacial Drift is invariably hard.

On the west side of the Warwickshire Coalfield around Solihull, the drifts consist of brown stratified sands, in the east, and unbedded clays with gravel and sand, in the west. Though they do not exceed a thickness of 25 feet, and appear to thin out southwards, they cover the greater part of the area. No flints have been met with on the west side of the coalfield south of Shustoke; Bunter pebbles predominate, and blocks of a white siliceous sandstone occur in the unbedded drifts between Solihull and Shirley.

Staffordshire.—The red sandy clays and roughly stratified sands and gravels of the western drifts which cover the central part of the South Staffordshire Coalfield to a depth of 60 feet or more end off against the high ground south of Cheslyn Hay. They come in again on the low-lying ground to the west, but are irregularly distributed and probably do not exceed 50 feet in thickness. West of Penkridge Mr. Dixon finds reason to think that the Keuper Waterstones and Marls are at or near the surface, but that a nearly continuous sheet of glacial deposits extends to the south-east up to Saredon Brook. Between Four Ashes and Coven Dr. Sherlock finds these drifts forming a water-logged alluvial-like flat which continues towards Bushbury. North of Tettenhall Mr. Dewey has observed that the drifts end off against an abrupt rise, leaving bare a broad area of Lower Keuper Sandstone. Farther west thin

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clayey drifts come on again, and between Kiddemore Green and Boscobel Dr. Sherlock finds isolated kame-like mounds of sand and gravel forming conspicuous objects in the landscape. Farther south, around Codsall, a similar group of hillocks of sand and gravel, in an otherwise nearly driftless region, has been observed by Mr. Dewey.

A line of railway, now in course of construction, follows the Staffordshire and Worcestershire Canal between Dunstall Park and Compton and then crosses hilly ground to Kingswinford. The following notes upon the cuttings have been made by Mr. Dewey.

The first part of the line runs through the gap parallel with the Keuper escarpment near Tettenhall Wood and crosses in it the watershed dividing the Penk from the Smestow.

A cutting through a hill of Upper Mottled Sandstone about 500 yards north of Compton shows 14 feet of variegated red sand overlain here and there by chocolate-coloured till. In the next cutting, in the same formation, there is a thin seam of green marl.

In the third cutting, about 200 yards south of Compton, there are traces of drift resting on the Bunter Beds, while in the fourth cutting chocolate till increases from a foot to 20 feet in thickness, and merges gradually into sandy drift. In a neighbouring sand-pit a similar section indicates a relation of the drift to the Tettenhall gap, for the glacial beds rest in channels running parallel with the gorge at several levels on the hill-slope, the lowest being practically at river-level. In this pit upwards of twenty varieties of rock were found by Mr. Dewey, including boulders from South Scotland, the Lake District and North Wales.

The fifth cutting is about 2,500 yards long and in places 40 feet deep, the whole depth, with the exception of a foot or two at the base, being in various kinds of glacial deposits. These consist mostly of unstratified, almost stoneless, brown clay, with occasional boulders of granite, granophyre and other rocks. They overlie red Bunter sands which have been cemented locally into hard sand-rock. Near Langley Farm several eskers have been cut through. Sand gradually replaces brown clay from above downwards, and gently undulating clay-lands give place to crescentic mounds arranged *en echelon* one of which embraces a small mere. These mounds consist of some 15 feet of either strongly current-bedded sand and seams of pebbles, or unbedded masses of pebbles and boulders. The pebbles include many varieties of igneous rock, also cannel coal, Keuper skerries, crinoidal and lithostrotion limestone, sandstone and quartzite.

Immediately beneath the bridge by Langley Farm the cutting lies entirely in a mass of large boulders, many bearing glacial striations. The boulders lie in a loamy matrix which passes into stiff clay near the next bridge, but still contains many boulders. Between this bridge and the end of the cutting there is ten feet of unstratified and almost stoneless clay, with large blocks of igneous rocks at its base, resting on red mottled sand. The last part of this cutting near Lower Penn is all in glacial gravel. The next cutting shows 40 feet of good moulding sand of Bunter age. No shells were noticed in any of the cuttings.

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SCOTLAND.

West Highland District.

C. T. Clough, M.A., LL.D., District Geologist.

E. B. Bailey, B.A.
E. M. Anderson, M.A., B.Sc.
G. V. Wilson, B.Sc.
} Geologists.

The only officer engaged in field survey in this district was Mr. Wilson. Prior to joining His Majesty's Forces in September, Mr. Bailey made a coloured copy of his own, Mr. Symes's, Mr. Wright's and Mr. Richey's work in one-inch Sheet 44, in order to facilitate the dry-proofing of this complicated area. He also sketched the general outlines of the memoir describing this Sheet, and wrote contributions to a considerable number of the chapters proposed.

Mr. Wilson surveyed small areas in one-inch Sheets 43, 51 and 52. In the spring he was employed in various parts of Scotland examining veins of barytes and preparing descriptions of them for 'The Mineral Resources of Great Britain,' Vol. II. (*see* p. 41).

Tobermory.—Mr. Wilson continued the mapping near Tobermory and confirmed the results of Professor Judd's[1] much earlier examination. The country consists in the main of basaltic lava-flows resting, where the base can be seen, either on Triassic or Jurassic rocks. To the west of Rudha nan Gall a small exposure of Jurassic rocks on the beach continues westwards to form a white scar which is just covered at low water, and can be seen to stretch along the coast-line to Ardmore Point. The thickness of lavas preserved in this area is about 1,500 feet.

An interesting N.N.W. dyke, about 18 ft. wide, has been traced at intervals, though not always on the same line, from three-quarters of a mile east of Caol Lochan nearly to Bloody Bay, a distance of about three miles. This dyke is characterised by the presence of large porphyritic felspar crystals, some of them as much as 8 in. long and 5 in. broad.

Ulva Ferry.—Mr. Wilson mapped an interbedded volcanic ash which is about 100 ft. thick near Laggan Ulva, but thins off rapidly to the south and south-west, being about 10 ft. near Oskamull, and only 3 ft. on the west shore of the Sound of Ulva. The overlying lava is of a mugearitic character, and at the foot of Eas Fors, the waterfall by the roadside a mile north-west of Laggan Ulva, the base shows large pipe-amygdales, 1½ in. broad and 1 to 2 ft. in length. A large mass of platy rock, about half-a-mile in diameter, forms the headland of Na Torranan, near Laggan Ulva, and in all probability belongs to a volcanic neck. It shows a vertical junction with the ash just west of the house, and appears also to include a large mass of highly baked ash. The platy rock is apparently rather too basic to be classed as a mugearite.

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[1] 'The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands.' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, Pl. xxxi, and p. 741.

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Central Highland District.

Work was carried on in Inverness-shire, Sheet 63, by Mr. Hinxman, who surveyed 14 square miles of area with 40¼ miles of boundary in the district between Laggan and Dalwhinnie.

Mr. Hinxman also visited several localities in Perthshire and Argyllshire for the purpose of obtaining additional information necessary for the completion of Sheet 54.

The normal work of the field staff and the carrying out of the programme of field work originally laid down for 1915 has been to a large degree interrupted by special investigations connected directly or indirectly with the War.

Mr. Carruthers was engaged during the spring and early summer in the preparation of a report on barytes and witherite in the North of England. During this period he was attached to the English staff. The results of this work are published in the Special Reports on the Mineral Resources of Great Britain, Vol. II. (*see* p. 41). He also visited borings put down by the Admiralty near Berwick-on-Tweed.

Mr. Dinham prepared a report on the potash felspar contained in the larger and more accessible veins of pegmatite on the north-west coast of Sutherland.

Inverness-shire.

METAMORPHIC AND IGNEOUS ROCKS OF THE HIGHLANDS.

The mapping of the western margin of the Laggan Granite in the region between Loch Ericht and the valley of the Spey has been continued by Mr. Hinxman. The area presents the usual complex of igneous and metamorphic rocks, and it is interesting to note in view of the observations recorded by Mr. Read in last year's 'Summary of Progress,' that in this region, where the altered sediments involved in the complex are almost entirely pelitic in character, the granite contains abundant biotite, in contrast with the eastern side of the intrusion where the schists are mostly of the siliceous type and the granite is highly acid in composition.

PLEISTOCENE AND RECENT.

The examination of the conspicuous dry valley that crosses the main watershed of the country between Inverpattack and Strath Mashie has afforded evidence of the passage, at more than one period, of the waters of the Pattack and of the upper part of Glen Spean eastwards through Strath Mashie to the Spey. The river Mashie, which occupies the lower part of the hollow, is but a small stream, quite out of proportion to the size of the valley.

Little more than 100 yards to the west of the watershed the river Pattack bends suddenly at an acute angle and flows westwards to Loch Laggan: the stream, both above and for some distance below the bend, passes through a rock-gorge which is still in process of erosion. The constricted part of the dry valley at the watershed evidently represents a river-gorge at a higher level. The lowest point on the col, where it is crossed by the dry channel, is 848 feet above sea-level, seven feet below the mean height of the Glen Spean lake-terrace as shown on the O.S. map, and practically on the same

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level as the top of the river-bank at the bend. It is probable, however, that the bottom of the dry gorge is filled up to some degree with superficial deposits.

Fragments of a higher terrace, composed of well-rolled coarse and fine gravel with lenticular beds of sand, can be traced on either side of the valley both east and west of the watershed. The elevation of this terrace above sea-level is 864 feet—almost exactly that of the highest level of the Glen Spean terrace and of the third or lowest of the parallel roads of Glen Roy.

Ayrshire.

KILMARNOCK DISTRICT.

C. T. Clough, M.A., LL.D., District Geologist.
E. M. Anderson, M.A., B.Sc.
G. V. Wilson, B.Sc. } Geologists.

CALCIFEROUS SANDSTONE SERIES.

The Hills north-west of Dalry.—Mr. Wilson revised an additional area of the ground in the north-west portion of Sheet 22. He found that mugearitic lavas increase in number near the large volcanic neck of which Knockside Hills form a part. A noteworthy fact is that nearly every band of interbedded ash or sediment is associated with a mugearitic lava. This suggests that the changes from basic to more acid type of lava were often accomplished during explosive periods.

CARBONIFEROUS LIMESTONE SERIES.

Galston.—Mr. Anderson states that a coal at least 1 ft. 6 in. in thickness, and possibly a good deal more, has been wrought along both banks of the Polbaith Burn near Castlehill. This seam occupies a position somewhere in the group of Limestone Coals.

COAL MEASURES.

Galston.—In the part of the Irvine Valley lying between Hurlford and Galston the lowest workable seam is the Hurlford Main Coal. Mr. Anderson reports that this coal reaches sometimes as much as 7 ft. 6 in. in thickness. Along with the Stone Coal it is usually classed as a steam-coal, but the Major, Tourha and McNaught, while variable, are mainly suitable for household use. What is probably the lower leaf of the McNaught is here more widely separate, and is sometimes wrought by itself under the name of the Ground or Jewel Coal.

As a whole the coals above-mentioned are thicker in this district than in the western part of the Kilmarnock Coalfield. The underlying seams in the Coal Measures are, however, thinner and unworkable, which is the more to be regretted as the seams above have now been probably more than half exhausted.

ECONOMICS.

Reference has been made in two previous Summaries[1] to a hard buff-coloured, or perhaps more often white clay, immediately overlying the topmost lava of the Millstone Grit volcanic series, and of persistent occurrence in northern Ayrshire. Two analyses of

[1] 'Summary of Progress' for 1913 (*Mem. Geol. Survey*), 1914, p. 65. *Ibid.* for 1914, p. 48.

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specimens from this horizon have shown the following amounts of silica and alumina present.[1]

	Lab. No. 464. Annick Water.	Lab. No. 457. Saltcoats.
SiO_2...	43·80	28·65
Al_2O_3	35·15	47·57

Although the amount of silica present would probably preclude the use of this material for the preparation of aluminium, it is possible that material containing so high a percentage of alumina might be worth attention in some other way.

Attention may also be called to the highly refractory character of a fireclay from the Millstone Grit at Monk Castle near Dalry. The clay has been analysed and submitted to physical tests (p. 29).

Lanarkshire and Renfrewshire.

Carluke and Morningside District.

L. W. Hinxman, B.A., District Geologist.

R. G. Carruthers.
M. Macgregor, M.A.
C. H. Dinham, B.A.
} Geologists.

Carboniferous Limestone and Millstone Grit.

The revision of the ground along the northern margin of Sheet 23, to the east of Morningside, by Mr. Macgregor and Mr. Hinxman, has shown the necessity of a considerable modification of the existing map of that region. The journals of a number of bores, recently put down in the Auchterhead district by the Coltness Iron Company, have been kindly communicated to the Survey by the Managers of the Company, with the result that much light has been thrown upon the structure of an area about which little was previously known.

From these bores it is evident that the system of folding found in the Carluke and Wilsontown areas prevails also in this district. The strata on the north side of the Castlehill-Wilsontown fault are thrown into a succession of domes and shallow basins; these are further complicated by the presence of several faults which cross the area in a W.N.W.–E.S.E. direction, and are cut off on the south by the Wilsontown fault.

In the bore-sections referred to above, the position of the Castlecary or Levenseat Limestone cannot be satisfactorily determined, there being no evidence of the occurrence of any definite limestone-horizon at the usual distance below the Curdly Ironstone and Cement Limestone position, which can generally be recognised. The sudden and considerable decrease in the distance between the latter horizon and the Gair Limestone as compared with the Fauldhouse district, a short distance to the north, suggests the possi-

[1] See pp. 28–29 for more complete analyses of these specimens.

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bility that the absence of the Castlecary Limestone may be due to local erosion at the base of the Millstone Grit, as is known to be the case on the west side of the Clyde in the Larkhall district.

The Lyoncross Limestone, intermediate in position between the Orchard or Gillfoot and the Index, is usually well developed in this district, though nowhere exposed at the surface.

COAL MEASURES.

The area of Coal Measures revised by Mr. Macgregor in the Crindledyke and Morningside district forms the eastern margin of the Wishaw coalfield and is faulted on the north-east against rocks of Millstone Grit age.

The highest coal present is the Ell, which outcrops a little to the west of Morningside Station. The higher seams—the Ell, Main, Splint and Virtuewell—are worked out, and coal is at present raised at Chapel and Morningside Collieries from the Kiltongue, Lower Drumgray and Smithy seams. The nomenclature of the coals in this and the adjoining areas has led to some confusion; a table of local names is given below.

Morningside.	*Bailliesmuir and Heirdshill.*	*Castlehill.*	*Shotts.*
Upper Drumgray	Up. Drumgray...	2 ft. Coal, Ball, or Upper Drumgray	Furnace Coal.
Lower Drumgray	Mid Drumgray...	4 ft. Coal or Mid Drumgray	Laigh Coal.
Smithy	Lower Drumgray	Smithy or Lower Drumgray	Smithy.

CONTEMPORANEOUS IGNEOUS ROCKS.

During the autumn Mr. Dinham revised two area of lavas of Calciferous age extending along the margin of Sheets 22, 23, between Eaglesham and Strathaven.

The lavas in the neighbourhood of Strathaven are predominantly of a basic type with olivine; tuffs and ashes are rare, and terraced features due to the outcrops of separate flows are notably absent. Around Eaglesham the lavas, on the contrary, are much more acid in character, and are accompanied by a considerable development of ashy beds, while the outcrop of the flows gives rise to distinct features in the landscape.

The Calciferous lavas of the Paisley district (Sheet 30) were revised by Mr. Carruthers.

A number of small exposures of basic igneous rock in the district east and north-east of Lanark have been examined by Mr. Hinxman. These are represented on the original survey as isolated bosses of 'greenstone,' intrusive in Lower Old Red Sandstone at Harelaw and Netherton, West Forth; and in the Calciferous Sandstone on either side of the Clyde, between Carnwath and Petinain. They are now all believed to form part of one or more lava flows of Calciferous Sandstone age. The sedimentary rocks with which they are associated are decidedly of Calciferous Sandstone type, while the lavas have been referred to the Dalmeny type of basalt and to the mugearite group.

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III.—PETROGRAPHICAL WORK.

England and Wales.

Petrographical work has been called for in connection with the re-survey of the North Wales coalfield and the Midland district.

In addition to drawing up a report on the part played by pyrites in the production of 'gob-fires' in coal-mines, and reporting on rocks submitted by the Road Board, Dr. Thomas has been engaged mainly in dealing with inquiries of an economic and scientific nature and assisting in the preparation of economic memoirs.

Scotland.

The Scottish petrographical work carried on in the London office has been, as in previous years, in connection with the survey of the island of Mull and the volcanic and intrusive rocks of the Ayrshire coalfield. Most of the results of this work have been incorporated in the field-descriptions given on previous pages.

IV.—CHEMICAL WORK.

In 1914 the Geological Survey Laboratory was placed under the charge of Mr. F. R. Ennos, of the staff of the Government Laboratory. Mr. E. G. Radley has continued to work in the Geological Survey Laboratory, and has made those analyses to which his name is appended.

In 1915 the complete analyses which follow have been made. In addition estimations were made of vanadium in coal, of iron and manganese in their respective ores, of total and available alumina in certain bauxitic clays, and of soda and potash in the Sutherland pegmatites. The last-named analyses appear in 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Survey*) Vol. 5, 1916, p. 11.

Complete analyses of a limestone and seven clays, together with the physical tests for the latter, have been completed at the Government Laboratory.

9247. Lab. No. 427. Granite. Large Quarry, 1 mile N. of Church, Lundy Island. Sheet 275.

9206. Lab. No. 430. Crinanite or Analcite Dolerite. Five foot dyke, centre of cove, N. of Mermaid's Hole, Lundy Island. Sheet 275.

16808. Lab. No. 407. Subophitic Olivine Dolerite. Tertiary dyke, on shore ¼ mile S.S.E. of Kintallen, and 2½ miles N.N.W. of Salen, Mull.

Slice No. ...	E9247.	E9206.	16808.
Lab. No. ...	427.	430.	407.
SiO_2	74·87	44·21	47·35
TiO_2	·05	2·58	1·75
Al_2O_3	13·89	16·38	13·90
Fe_2O_3	·52	5·26	5·87
BeO	·10	—	—
FeO	1·06	7·80	8·96
MnO	·05	·21	·23
CaO	·44	8·65	10·65
MgO	·01	6·78	5·97
K_2O	4·39	·47	·54

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Slice No. ...	E9247.	E9206.	16808.
Lab. No. ...	427.	430.	407.
Na_2O	3·47	2·97	2·73
Li_2O	·16	nt. fd.	nt. fd.
H_2O at 105° C.	·08	2·35	1·04
H_2O above „	·58	1·77	1·16
P_2O_5	·05	·32	·24
S	nt. fd.	·16	·23
CO_2	·06	·29	·32
F	·22	—	—
	100·00		
Less O for F	·09		
Total ...	99·91	100·20	100·94

18455. Lab. No. 437. Basic portion of differentiated gabbro-granophyre mass. Quartz-gabbro. Rather more than ½ mile W.N.W. of Corra-bheinn, Mull. Sheet 44. The basic felspars are much albitized and albite with original quartz occur interstitially. (ANAL. E. G. RADLEY.)

18456. Lab. No. 438. Specimen of intermediate composition from the same mass as the above. Fully ¼ mile W.S.W. of Trig. Sta. on Corra-bheinn, Mull. Sheet 44. There is a marked increase in the proportion of quartz and alkali-felspar and the augite has a tendency to assume acicular form. (ANAL. E. G. RADLEY.)

Slice No. ...	S18455.	S18456.
Lab. No. ...	437.	438.
SiO_2...	50·04	57·18
TiO_2...	2·56	3·25
Al_2O_3	13·32	10·75
Fe_2O_3	4·71	4·96
FeO	8·07	6·24
MnO	·33	·32
(CoNi)O	nt. fd.	nt. fd.
BaO	nt. fd.	·06
CaO	10·02	5·73
MgO	5·01	2·15
K_2O	1·08	2·67
Na_2O	3·28	4·62
Li_2O	trace	trace.
H_2O at 105°C	·27	·33
H_2O above „	1·45	1·31
P_2O_5	·28	·46
FeS_2	nt. fd.	nt. fd.
Co_2	·08	·08
Total ...	100·50	100·11

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18460-63. Lab. Nos. 439-442. These four analyses illustrate the progressive differentiation of the newer gabbro of Glen More, Island of Mull. Sheet 44. Compare with Nos. 437 and 438.

18460. Lab. No. 439. 130 yds. E.S.E. of Trig. Sta. on Cruach Choireadail, Mull. Sheet 44. This rock consists of acicular crystals of uralitised augite and crystals of basic plagioclase felspar, in a feathery matrix of albite with subordinate orthoclase and quartz occasionally showing granophyric structure. (ANAL. E. G. RADLEY.)

18461. Lab. No. 440. Fully ½ mile S.S.E. of Trig. Sta. on Cruach Choireadail Mull. Sheet 44. Compared with the above, augite is moderately abundant in granular to sub-idiomorphic crystals. There is a greater amount of basic plagioclase but the matrix, although forming a smaller proportion of the rock, is of a similar character. (ANAL. E. G. RADLEY.)

18462. Lab. No. 441. Same locality as the above. This rock is a somewhat abnormal type of quartz gabbro. The augite is sub-ophitic. Olivine is represented by pseudomorphs in secondary hornblende. The felspar is mostly a basic plagioclase but some granophyric material occurs interstitially. (ANAL. E. G. RADLEY.)

18463. Lab. No. 442. Half-a-mile W.N.W. of Creag na h-Iolaire, Mull. Sheet 44. Quartz gabbro of a more basic type. Similar to the above, but with less interstitial granophyric matter. (ANAL. E. G. RADLEY).

Slice No. ...	S18460.	S18461.	S18462.	S18463.
Lab. No. ...	439.	440.	441.	442.
SiO_2	68·12	56·22	51·32	49·90
TiO_2	1·26	2·74	·98	2·56
Al_2O_3 ...	13·08	12·45	13·96	12·70
Fe_2O_3 ...	1·02	3·09	2·48	4·20
FeO	3·26	7·58	7·10	7·88
MnO	·39	·43	·34	·36
(CoNi) O ...	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	·04	·04	nt. fd.	nt. fd.
CaO	1·81	5·93	11·51	10·39
MgO	·71	2·78	5·78	5·88
K_2O	4·47	2·67	1·16	·95
Na_2O ...	4·15	3·82	3·50	2·86
Li_2O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·40	·44	·36	·67
H_2O above „	1·16	1·35	1·27	1·65
P_2O_5... ...	·22	·50	·24	·20
FeS_2... ...	nt. fd.	nt. fd.	nt. fd.	nt. fd.
CO_2	·06	·05	·09	·09
Total ...	100·15	100·09	100·09	100·29

18464. Lab. No. 443. S. of Coire Buidhe, between the 800 and 900 contours about ½ mile N. of Carsaig, Mull. Sheet 44, Felsite. The rock consists of micro-porphyritic crystals of alkali-felspar, in a fine-grained felsitic ground-mass containing abundant skeletal and acicular crystals of uralitic hornblende. The rock is allied to the Inninmorites (Summary of Progress for 1914, p. 54).

18467. Lab. No. 444. Inclined sheet, about 70 yds. S. of summit of Cruachan Dearg, Mull. Sheet 44. Basic variety of the Talaidh type of inclined Tertiary sheets.

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Slice No.	S18464.	S18467.
Lab. No.	443.	444.
SiO_2	70·70	52·16
TiO_2	1·27	3·25
Al_2O_3	11·78	11·95
Fe_2O_3	1·32	4·86
FeO	3·45	9·92
MnO	·07	·18
(CoNi)O	—	—
BaO	—	—
CaO	1·30	7·14
MgO	·53	3·77
K_2O	4·71	1·74
Na_2O	2·48	2·36
Li_2O	nt. fd.	nt. fd.
H_2O at 105° C	·50	·56
H_2O above „	1·14	1·95
P_2O_5	·26	·24
S	·08	·18
CO_2	·51	·18
Total	100·10	100·44

18469. Lab. No. 445. Porphyritic basic augite andesite lava. ½ mile S.S.W. of Derrynaculen, Mull. Sheet 44. The rock consists of small porphyritic crystals of anorthite in a fine grained matrix of augite, microlithic labradorite and magnetite. (ANAL. E. G. RADLEY.)

18471. Lab. No. 446. Porphyritic basic augite andesite lava. ⅜ths of a mile N.E. of Trig Sta. Cruach Doire nan Cuilean, Mull. Sheet 44. The rock is similar to the above, 18469. (ANAL. E. G. RADLEY.)

18472. Lab. No. 447. Pillow-lava. Porphyritic basic augite andesite. ¼ mile E. of S. of Trig Sta. Cruach Choireadail, Mull. Sheet 44. Closely packed porphyritic crystals of albitised anorthite in an intersertal to variolitic and augite-rich matrix. (ANAL. E. G. RADLEY.)

18474. Lab. No. 448. Non-porphyritic compact augite andesite lava. Somewhat decomposed. Stream S.E. of Monadh Beag, and 1,000 yards slightly W. of N. of Ishriff, Mull. Sheet 44. (ANAL. E. G. RADLEY.)

Slice No.	S18469.	S18471.	S18472.	S18474.
Lab. No.	445.	446.	447.	448.
SiO_2	47·24	48·51	47·49	50·54
TiO_2	1·46	1·46	·93	2·80
Al_2O_3 ...	18·55	19·44	21·46	12·66
Fe_2O_3 ...	6·02	5·66	1·72	4·13
FeO	4·06	4·00	4·80	8·75
MnO	·31	·23	·15	·32
(CoNi)O ...	·05	·04	·04	·06
BaO	nt. fd.	nt. fd.	nt. fd.	nt. fd.
CaO	11·72	12·03	13·24	8·74
MgO	5·24	5·12	4·59	4·63
K_2O	·15	·25	·42	1·43

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Slice No.	S18469.	S18471.	S18472.	S18474.
Lab. No.	445.	446.	447.	448.
Na_2O ...	2·42	2·53	2·17	2·89
Li_2O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
H_2O at 105°C	·21	·04	·17	·17
H_2O above „	2·24	·48	2·54	2·25
P_2O_5... ...	·26	·16	·43	·34
FeS_2	nt. fd.	nt. fd.	nt. fd.	nt. fd.
CO_2	·19	·09	·08	·33
Total ...	100·12	100·04	100·23	100·24

19069. Lab. No. 459. Gabbro. About 1,500 ft. contour S.E. of summit of Ben Buie, Mull. Sheet 44.

19070. Lab. No. 460. Fresh micro-ophitic olivine basalt allied to the Jedburgh type. Raised-beach cliff 200 yards W. of Loch Aline Pier, Mull. Sheet 44. This rock is representative of a large suite of the Tertiary lavas, but unlike most of the lavas of Mull has its olivine in a relatively fresh condition.

19071. Lab. No. 461. Micro-porphyritic olivine basalt. Tertiary lava. As in the above the olivine is in an undecomposed state. Little port on E. side of Rudha Dearg. 1 mile W. of Loch Aline, Mull. Sheet 44.

Slice No. ...	S19069.	S19070.	S19071.
Lab. No. ...	459.	460.	461.
SiO_2	46·66	45·48	45·52
TiO_2	·47	3·48	2·85
Al_2O_3	16·71	15·66	14·30
Fe_2O_3	2·69	3·64	3·43
FeO	5·87	10·56	9·00
MnO	·12	·20	·19
(CoNi)O	—	—	—
BaO	—	—	—
CaO	12·57	8·24	9·54
MgO	12·36	6·99	10·65
K_2O	·27	·49	·42
Na_2O	1·16	2·68	2·21
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·13	·93	·70
H_2O above „	1·24	1·52	1·53
P_2O_5...	·13	·26	·23
S	nt. fd.	nt. fd.	nt. fd.
CO_2	·18	·21	·15
Total ...	100·56	100·34	100·72

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19106. Lab. No. 458. Oolitic Jurassic Iron-ore. Main Mine, Raasay,[1] Inverness-shire. Sheet 81. (ANAL. E. G. RADLEY.)

The oolitic grains are of a green iron silicate with carbon or iron-pyrites as nuclei.

Lab. No. 458A. Oolitic grains separated by hand from the above. Lab. No. 458. (ANAL. E. G. RADLEY.)

Lab. No. 464. Fireclay, in a bed over 2 ft. thick, overlying Millstone Grit lavas, left bank of R. Annick, 500 yds. E.S.E. of Fairliecrevoch, Ayrshire. Sheet 22. (ANAL. E. G. RADLEY.)

Slice No.	19106.	—	—
Lab. No.	458.	458A.	464.
SiO_2	8·58	20·62	43·80
TiO_2	·28	·72	3·69
Al_2O_3	4·24	11·96	35·15
Fe_2O_3	1·24	5·11	1·01
Cr_2O_3	nt. fd.	nt. fd.	—
FeO	11·79	25·98	—
MnO	·65	·30	·06
(CoNi)O	·04	·06	nt. fd.
BaO	nt. fd.	nt. fd.	—
CaO	35·43	11·50	·23
MgO	1·71	3·07	·07
K_2O	·02	nt. fd.	·50
Na_2O	·08	·09	·40
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C	1·37	2·56	1·54
H_2O above „	4·44	8·36	13·40
P_2O_5	1·68	5·11	·26
FeS_2	·72	·71	nt. fd.
Fe_7S_8	·15	nt. fd.	—
SO_3	·15	nt. fd.	—
C	·26	·25	—
CO_2	27·54	3·94	·12
Total	100·37	100·35	100·23
"Soluble Al_2O_3"	—	—	7·35

A 'commercial' analysis of Lab. No. 464, gave the following results: SiO_2 = 43·54%, TiO_2 = 3·70%, Al_2O_3 = 38·57%, Fe_2O_3 = 1·01%, combined water = 13·40%. Total = 100·22%. (ANAL. E. G. RADLEY.)

Lab. No. 436. Vienna Chalk. Calcined dolomite of unusual purity.

Slice No.	—
Lab. No.	436
SiO_2	·66
TiO_2	—
Al_2O_3	—

[1] H. B. Woodward, *Trans. Geol. Soc. Edin.*, vol. x, p. 164.

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Slice No.	—
Lab. No.	436
Fe_2O_3	·17
FeO	—
MnO	—
CaO	56·42
MgO	36·07
K_2O	—
Na_2O	—
Li_2O	—
H_2O at 105°C	4·52
H_2O above „	
P_2O_5	—
SO_3	—
CO_2	2·65
Total	100·49

Lab. No. 435. Ironstone from the decomposed uppermost lavas of the Millstone Grit Series. Bed of Fenwick Water, rather less than ½ mile N.N.W. of Assloss House. One-inch map 22. Ayr. 18 N.W.

% Fe = 34·86

Lab. No. 455. Manganese Ore interstratified with the Harlech Grits. Cwm yr Avon, near Llanbedr, Merionethshire.

% Mn. = 34·47

Mainly in the form of Carbonate, about 20% of CO_2 being found.

Slice. No. 16103. Lab. No. 457. Clay overlying Millstone Grit lavas. Shore at Saltcoats ¼ mile N.W. from bathing-pond. One-inch map 22. Ayr. 16 N.W.

"Soluble" Al_2O_3	...	4·37%
Total Al_2O_3	... ...	47·57%

(Anal. E. G. Radley.)

The following analyses were made at the Government Laboratory, Clement's Inn Passage, W.C., by similar methods to those described in the Glasgow District Memoir, 1911.

Govt. Lab. No 1. Hard Clay from the lower part of the Grey Coal Measures of the Warwickshire coalfield. About 40 ft. below the 'Seven Feet' Coal. Messrs. Skey & Co.'s Tileworks, Wilnecote by Tamworth.

Govt. Lab. No. 2. White Clay from Warwickshire coalfield. 75 ft. below the 'Seven Feet' Coal. Messrs. Skey & Co.'s Tileworks, Wilnecote by Tamworth.

Govt. Lab. No. 3. Unctuous clay, hard clay shale from Warwickshire coalfield. About 200 ft. below the 'Seven Feet' Coal. Messrs. Skey & Co.'s Tileworks, Wilnecote by Tamworth.

Govt. Lab. No. 4. 'Upper Fireclay,' associated with coal and gannister in the upper portion of the Millstone Grit. Bonnyside Firebrick Works, Bonnybridge, Stirlingshire.

Govt. Lab. No. 5.[1] 'Upper Fireclay' from Bonnyside Firebrick Works. Sample (2).

Govt. Lab. No. 6. 'Lower Fireclay' above the base of the Millstone Grit. Castlecary Fireclay Co.'s Works, Castlecary, Stirlingshire.

Govt. Lab. No. 54. Fireclay from the Millstone Grit. Monk Castle Pit, 1 mile South of Dalry, Ayrshire.

[1] This sample contained about 5 % of stones which were removed before analysis.

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'Rational' or 'Proximate' analyses of clays dried at 105° C.

Govt. Lab. No.	1.	2.	3.
Clay Substance	53·64	72·66	93·32
Quartz	45·84	26·72	6·40
Felspar	·52	·62	·28
	100.00	100·00	100·00
Calculated from ultimate analysis.			
Clay substance	47·21	55·12	77·08
Quartz	45·99	22·80	3·31
Felspar	6·80	22·08	19·61
	100·00	100·00	100·00

Govt. Lab. No.	4.	5.	6.	54.
Clay Substance...	92·63	97·14	88·00	79·20
Quartz	7·12	2·38	11·25	20·46
Felspar	·25	·48	·75	·34
	100·00	10·000	100·00	100·00
Calculated from ultimate analysis.				
Clay Substance...	86·90	92·29	83·80	77·43
Quartz	6·60	2·60	11·72	20·59
Felspar	6·70	5·11	4·48	1·98
	100·00	100·00	100·00	100·00

The accuracy of the results as determined for clay substance and felspar by 'Rational' analysis is open to considerable doubt. The matter has been discussed by H. Ries in 'Clays' (New York, 1906), p. 66, etc., and at some length by J. W. Mellor in 'Quantitative Inorganic Analysis' (Griffin), p. 657, etc.

Comparison between the results of the 'Rational' analysis and those calculated from the ultimate analysis shows that the felspar found in the 'Rational' analysis is in all cases very much lower than that calculated on the assumption that all the sodium and potassium oxide is present as felspar. The values for quartz are very much closer, and in five cases are in satisfactory agreement. The 'Rational' analysis is of considerable value for determining the proportion of quartz, but of doubtful value for ascertaining the clay substance and felspar in different kinds of clays. (*See also* Ries 'Clays,' p. 67).

Ultimate Analysis.

Govt. Lab. No.	1.	2.	3.
SiO_2	69·67	60·35	48·07
TiO_2	1·06	·92	·98
ZrO_2	0·03	nil	nil
Al_2O_3	18·21	24·21	31·06

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Govt. Lab. No.	1.	2.	3.
Fe_2O_3	·76	1·11	1·20
FeO	·64	·50	·92
MnO	·04	·01	·01
NiO	·01	nil	nil
BaO	trace	·01	·01
CaO	·53	·48	·58
MgO	·64	·83	·77
K_2O	·86	2·85	2·55
Na_2O	·19	·57	·45
Li_2O	·05	·09	·07
H_2O at 105°C	1·58	1·79	3·61
H_2O above „	5·86	6·27	9·16
P_2O_5	·05	nil	nil
FeS_2	·04	·06	·06
SO_3	·04	·04	·02
C (organic)	·12	·20	·89
CO_2	·07	·06	·02
Cl	·04	·03	·02
H (organic)	·04	·03	·05
Total	100·53	100·41	100·50
Loss on ignition ...	7·57	8·28	13·81

Govt. Lab. No.	4.	5.	6.	54.
SiO_2	47·95	45·07	50·10	54·78
TiO_2	1·51	1·12	1·21	1·26
ZrO_2	nil	nil	nil	·03
Al_2O_3 ...	32·74	34·22	31·16	28·52
Fe_2O_3 ...	1·22	·99	1·33	·88
FeO	·75	1·85	·90	·43
MnO	·01	·03	nil.	trace
NiO	nil	nil	trace	nil
BaO	trace	trace	·02	trace
CaO	·28	·24	·55	·82
MgO	·61	·63	·67	·25
K_2O	·97	·83	·74	·13
Na_2O ...	·10	·01	nil.	·14
Li_2O	·03	·03	·04	·02
H_2O at 105° C	1·83	2·00	2·33	2·03
H_2O above „	11·38	11·72	10·81	10·27
P_2O_5	nil	nil	trace	trace
FeS_2	·04	·06	·02	·13
SO_3	·01	·01	trace	trace
C (organic) ...	·57	·59	·33	·29
CO_2	·32	·88	·10	·36
Cl	·02	·02	trace	·01
H (organic) ...	·04	·04	·01	trace
Total ...	100·38	100·34	100·32	100·35
Loss on ignition	14·02	15·04	13·61	13·07

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An attempt was made to determine the organic matter more accurately than is usually considered necessary in clay analyses. The method consisted in determining the water given off at 1,000° C. on heating the clay in a stream of dry carbon dioxide. The total water formed after ignition in air or oxygen is also determined. The difference, amounting to 0·2 to 0·4 per cent., is taken as water formed from hydrogen combined with carbon. The carbon present otherwise than in the form of carbon dioxide is determined as follows. The total carbon is calculated from the amount of carbon dioxide obtained by burning the clay in a current of dry oxygen at 1,000° C. From the carbon so found there is deducted the amount due to the carbon present in the form of carbon dioxide as determined by treatment of the clay with hydrochloric acid in the usual way. The difference is due to carbon present, either as free carbon or as organic matter. The amount of hydrogen found in all cases in small, but there is no doubt as to its presence as distinct from that in combined water and water expelled at 105° C., seeing that the differences referred to above are altogether beyond the limits of experimental error.

The high ratio of carbon to hydrogen suggests that the carbon is present mainly, if not wholly, either as free carbon or as coal.

Physical Tests.

Govt. Lab. No.	1.	2.	3.
Tests on Unburnt Material.			
Sp. Gr. at 15·5° C.	2·592	2·624	2·519
Plasticity Number	16·3	24·8	23·2
Shrinkage on air drying	5·0%	5·0%	6·0%
Tensile strength lbs. per s. in. ...	129·0	186·6	148·6
Texture.			
Clay substance	37·15%	25·56%	65·86%
(Av. diam. mms.)	(·0089)	(·0097)	(·0076)
Silt	10·15%	67·59%	5·15%
(Av. diam. mms.)	(·0298)	(·0142)	(·0310)
Dust sand	4·36%	3·62%	3·05%
(Av. diam. mms.)	(·0343)	(·0386)	(·0413)
Sand	48·29%	2·38%	24·40%
(Av. diam. mms.)	(·226)	(·1248)	(·265)
Tests on Burnt Material.			
Sp. Gr. at 15·5°C of material burnt to 1200°C.	2·604	2·491	2·554
Shrinkage at 500°C	5·0%	5·0%	6·0%
„ „ 800°C	5·0%	5·0%	8·0%
„ „ 1,000°C	5·6%	8·2%	9·6%
„ „ 1,200°C	7·2%	10·4%	10·4%
Porosity after burning to 1,200°C...	4·57%	·08%	1·93%
Fusing point	Cone 27-28 1680°	Cone 26-27 1660°C	Cone 29-30 1720°C

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Govt. Lab. No.	4.	5.	6.	54.
Tests on Unburnt Material.				
Sp. Gr. at 15·5°C	2·564	2·564	2·548	2·549
Plasticity number... ...	15·6	12·1	14·0	11·3
Shrinkage on air drying ...	3·0%	3·0%	2·0%	3·0%
Tensile strength lbs. per s. in.	48·6	13·6	38·6	43·8
Texture.				
Clay substance	16·77%	6·79%	14·66%	14·27%
(Av. diam. mms.) ...	(·0178)	(·0096)	(·0126)	(·0134)
Silt	7·50%	11·35%	1·09%	6·89%
(Av. diam. mms.) ...	(·0290)	(·0163)	(·0201)	(·0235)
Dust sand	1·71%	·58%	9·08%	2·04%
(Av. diam. mms.) ...	(·0408)	(·0429)	(·0384)	(·0365)
Sand...	73·67%	80·36%	74·48%	77·37%
(Av. diam. mms.) ...	(·413)	(·200)	(·266)	(·506)
Tests on Burnt Material.				
Sp. Gr. at 15·5°C of material burnt to 1200°C	2·694	2·722	2·673	2·693
Shrinkage at 500°C ...	4·0%	3·0%	2·0%	4·0%
„ 800°C ...	5·0%	5·0%	4·0%	4·6%
„ 1000°C ...	5·4%	5·0%	4·8%	5·0%
„ 1200°C ...	8·0%	7·2%	6·6%	5·0%
Porosity after burning to 1200°C	5·50%	5·59%	6·65%	14·11%
Fusing point	Above cone 30. Above 1730°C.	Above cone 30. Above 1730°C.	Above cone 30. Above 1730°C.	Above cone 30. Above 1730°C.

NOTES ON THE ABOVE PHYSICAL TESTS.

1. *Plasticity Number.* This figure is the percentage amount of water, calculated on the dry clay, present in a mass of tempered clay of such constituency that a needle of 1 sq. millimetre area, under a load of 300 grams, sinks to a depth of 4 centimetres in the moistened clay in five minutes.

2. *Texture* or size of grain. The sizes given in brackets were determined by direct measurement of the grains of the four fractions, viz.:—'Clay substance,' 'silt,' 'dust sand' and 'sand' into which the clay was separated by the elutriation method of Schoene. The sizes so ascertained differ in some cases from those *calculated* by Schoene's method as the maximum sizes for the grains in each of his fractions, viz.:—for 'clay substance' 0·01 millimetre, for 'silt' 0·025 millimetre, for 'dust sand' 0·04 millimetre, and for 'sand' 0·2 millimetre and a little over. The texture was determined by 'Schoene's Method,' as described in Ries' 'Clays,' p. 138.

3. *Porosity.* This figure is the percentage weight of water absorbed by a burnt clay block after immersion for 24 hours, calculated on the weight of the block when dried at 100° C.

4. *Fusing-point.* The test for fusing-point refers to Seger's cones, a series of test-pieces made of mixtures of clays with fluxes

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so graded that they represent a series of fusion-points; the temperature of fusion as determined from the cone is also given in the table. According to Ries' classification all the clays are semi-refractory. The Scotch clays have fusion-points which are near the border line between the refractory and semi-refractory class, and they ought perhaps to be classed as refractory. The second of the Warwickshire clays is on the border line between low and semi-refractoriness. This clay produces ware of great compactness, as shown by the low porosity of the material burnt at 1,200° C.

Govt. Lab. No. 7.—The Castlecary Limestone at the top of the Carboniferous Limestone Series from the Castlecary Fireclay Co.'s Works, Stirlingshire :—

SiO_2	4·53
TiO_2	trace
Al_2O_3	1·74
Fe_2O_3	1·35
MnO	·10
NiO	·01
BaO	·03
CaO	48·96
MgO	1·60
K_2O	·13
Na_2O	·02
Li_2O	nil
H_2O at 105° C	·88
H_2O above „	·18
P_2O_5	trace
FeS_2	·71
SO_3	trace
CO_2	40·35
Cl	trace
Total...	100·59
Cementation Index	0·30

Ferrous oxide (FeO) was determined directly, and was found to amount to 0·97 per cent., but, as it is impossible in the presence of a sulphide to be sure that this value is correct, the whole of the iron has been calculated as ferric oxide and iron pyrites. The carbon dioxide present is no more than sufficient to combine with the lime and magnesia.

V.—PALÆONTOLOGICAL WORK.

England and Wales.

Much of the palæontological work has been in connection with the surveying now in progress and with the preparation of forthcoming Memoirs. Mr. Pringle has drawn up the fossil-lists for several sheet-explanations and has named large collections of Ordovician and Carboniferous fossils from North Wales, Staffordshire and Yorkshire. He has also examined and reported upon the fossils obtained by him in a previous year from the deep boring near Little Missenden, described on p. 43.

Mr. Pringle examined several deep borings in Kent, and

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obtained records and specimens which will be utilised in a Memoir now in course of preparation. As a contribution to this work, Dr. Kitchin has named extensive series of the Jurassic and Cretaceous fossils. This projected account supplements that dealing with the hidden Mesozoic rocks of Kent already published in a previous Memoir.

Mr. Allen's revision of the nomenclature of the Cretaceous Gasteropoda in the Museum is well advanced. A selection of similar specimens from the collection of the Geological Society has also been named, and, as far as space permits, incorporated in the museum-cases. The preparation of a catalogue of the types and figured specimens has been carried on concurrently, and is now published (*see* Appendix II, p. 47). Mr. Allen also contributed towards the revision of the palæontological matter contained in the Memoir on 'The Geology of the Country between Whitby and Scarborough.' The ammonites were dealt with by Mr. S. S. Buckman.

A series of friable fragments of bone and teeth, unearthed during excavations for Messrs. Barclay's Bank at the lower end of the Haymarket, were submitted for inspection by Mr. A. Blomfield, M.A., F.R.I.B.A. These were found by Mr. Allen to comprise remains of elephant, hippopotamus and ox. Hippopotamus had previously been recorded from the site of Messrs. Stanford's building at 26, Cockspur Street, about 100 yards from Messrs. Barclay's excavation.

The centenary-celebration of the birth of Edward Forbes, held in February, 1915, under the auspices of the London Manx Society, brought into notice that distinguished naturalist's official connection with this institution and his work in the fossil-department. The programme included a visit to the Museum, where a number of specimens described by Forbes, together with the publications in which the descriptions and illustrations appeared, were brought together on exhibition.

The following specimens in the Museum have been figured and described:—

In the Palæontographical Society's Volume for the Year 1914. (Published 1915.)

The Pliocene Mollusca, Part II.

By Mr. F. W. Harmer, F.G.S., F.R.M.S.

Pleurotoma inermis *Partsch, var.* nuda *S. V. Wood*, pl. xxvi, fig. 6, p. 207.
Drillia icenorum (*Wood*), *var.* speciosa *Harmer*, pl. xxvii, fig. 19, p. 222.
Bela borealis (*Reeve*), pl. xxxii, fig. 13, p. 298.

In the British Museum Catalogue of the Mesozoic Plants.

The Cretaceous Flora, Part II.

By Dr. Marie C. Stopes, D.Sc., F.L.S.

Bennettites maximus *Carruthers*, text-fig. 14, pp. 50–53.

In Yorkshire Type Ammonites, 1913, 1914.

By Mr. S. S. Buckman, F.G.S.

Paltopleuroceras regulare (*Simpson*), Part 10, No. 77.
Whitbyiceras pingue (*Simp.*), Part 10, No. 80.
Echioceras aureolum (*Simp.*), Part 12, No. 96.
Deroceras mutatum (*Simp.*), Part 14, No. 105.

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Fig. 1.—Vertical Section of the Lower Palæozoic Rocks of the Shelve-Chirbury Country.

Scale about 1 inch = 800 feet.

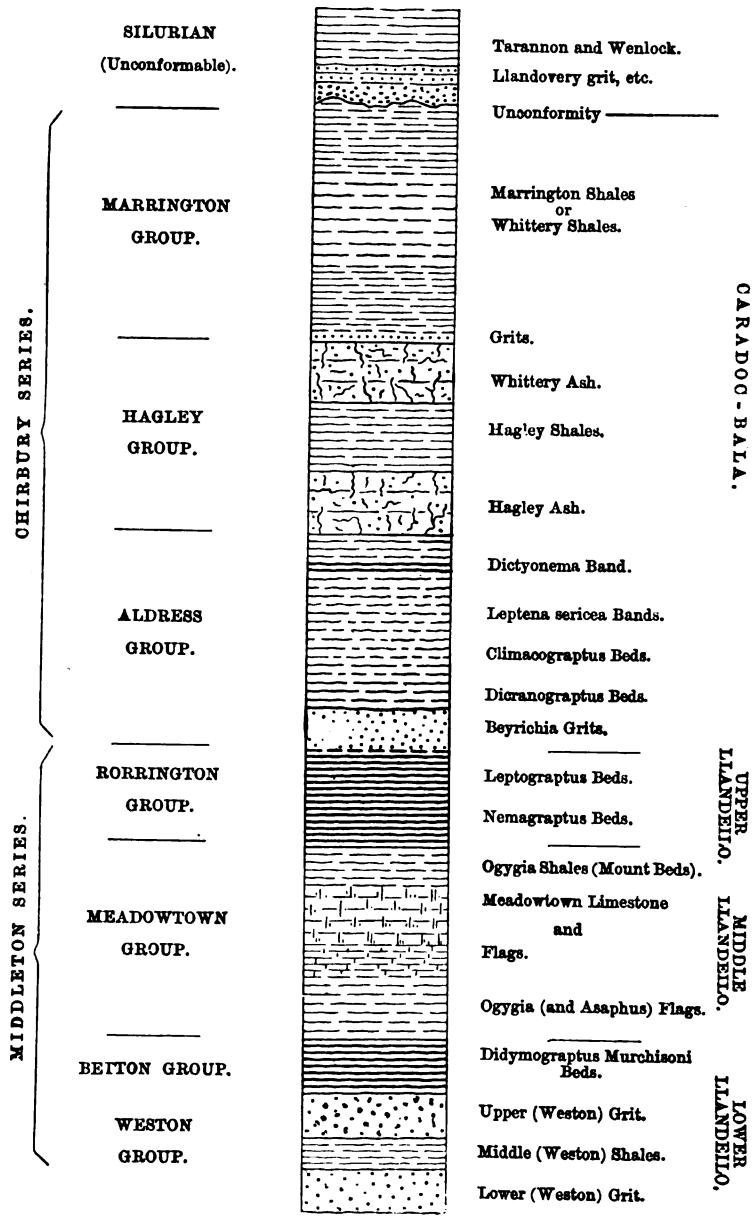

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Fig. 2.—VERTICAL SECTION OF THE LOWER PALÆOZOIC ROCKS OF THE SHELVE-CHIRBURY COUNTRY—*continued.*

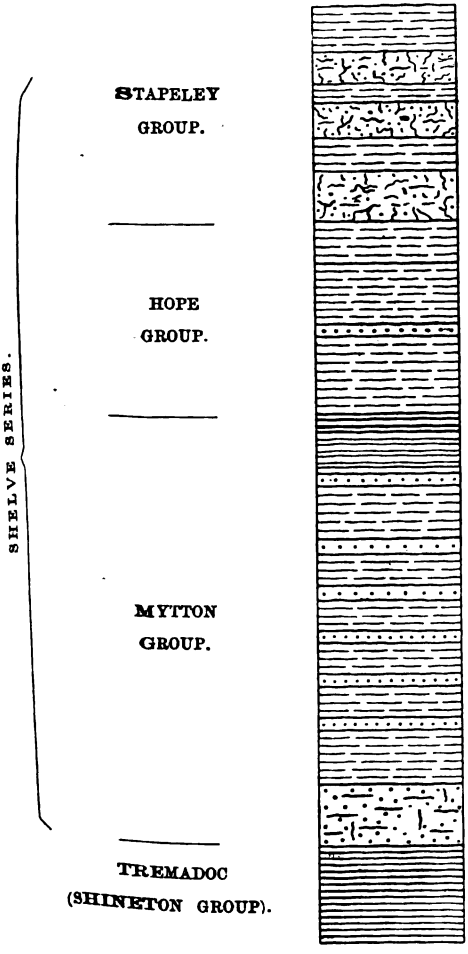

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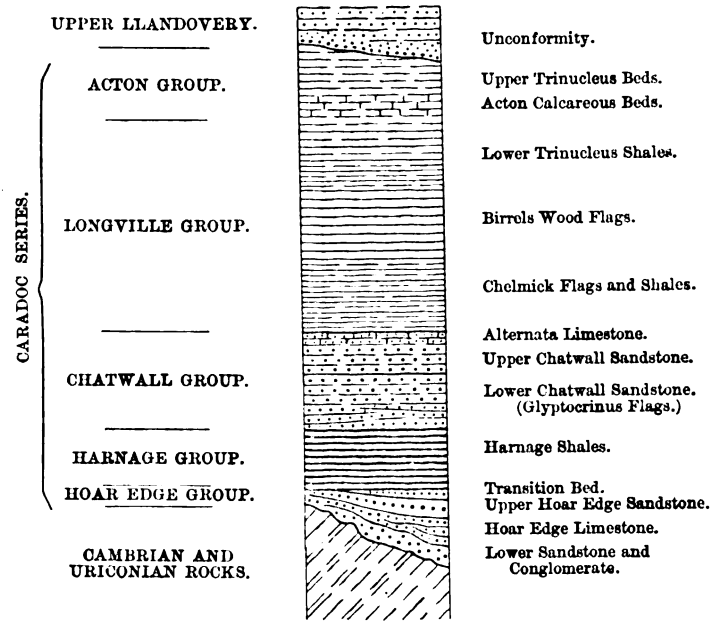
Fig. 3.—Vertical Section of the Lower Palæozoic Rocks of the Caradoc-Wrekin Country.

Scale about 1 inch = 800 feet.



Allusion was made in the 'Summary of Progress' for 1914, p. 57, to the collecting of fossils from the Lower Palæozoic rocks of Shropshire under the guidance of Professor C. Lapworth. The field-work has been completed for the present, and the specimens are undergoing examination. The results obtained by Professor Lapworth may be summarised as follows:—

About 150 localities were selected, ranging from the base of the Cambrian system to the top of the Caradoc-Bala formation, and preference was given to those which were richest in brachiopods and graptolites. The fossils recently collected, taken in conjunction with those collected in 1891 and 1892, are expected to afford a fairly complete conspectus of the strata in question. The brachiopods of 32 of the richest localities have been identified by Miss Silvester, the fossils of the Cambrian rocks of Comley by Mr. Cobbold, and the remainder by Professor Lapworth himself.

The foregoing figures have been drawn by Professor Lapworth to represent the stratigraphical sequence of the Ordovician rocks in the Shelve and Chirbury district and in the neighbourhood of the Wrekin. The broader grouping differs slightly from that adopted by the Survey of late years, in respect of the omission of the Llanvirn between the Arenig and Llandilo formations, and in the position of the lower limit of the Caradoc-Bala formation.

Scotland.

Two hundred and twenty-four fossils were collected and registered during the year. Most of them were obtained from the

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Carboniferous areas of Central Scotland, and they range from the Calciferous Sandstone to the Coal Measures. The most noteworthy collection is from Skipsey's Marine Band in the Coal Measures near Hamilton, which contains some remarkably well-preserved specimens of *Chonetes*.

There has been no further field-work done in the Jurassic Rocks of Scotland, but part of the materials collected has been examined by Mr. S. S. Buckman and Dr. G. W. Lee. Mr. Buckman's report proved to be of wide interest, but was not ready in time to be summarised here. It deals principally with the distribution of the fauna in the 'Pabba Shales' (*i.e.*, upper part of the Lower Lias). The Jurassic fossils examined by Dr. G. W. Lee are from Applecross in Ross-shire, and constitute a typical assemblage of Hettangian (*i.e.*, base of Lower Lias) forms. The numerous specimens of *Ostrea* in that collection may some day prove of value for an evolutionary study of the genus within the Lower Lias.

VI.—MUSEUM OF PRACTICAL GEOLOGY.

Specimens have been arranged for exhibition to illustrate the 'Special Reports on the Mineral Resources of Great Britain,' vol. 1, Tungsten and Manganese; vol. 2, Barytes and Witherite; vol. 3, Gypsum and Anhydrite, Celestine and Strontianite; vol. 4, Fluorspar.

A temporary exhibit has been arranged to illustrate the Memoir on Sheets 112 and part of 100, Derbyshire, in co-operation with the field-staff.

Two interesting loan-exhibits have been placed in the Museum. One from Lieutenant E. C. Eckel comprises a series of assayed samples of 'Caliche,' sodium nitrate, from Chile; the other, from the British South Africa Company, is a selection of fine mineral specimens from Rhodesia.

List of Donations during the year 1915.

Abbott, G., Esq.—Pseudomorphs from Roker, Durham.

Ashby, H., Esq.—A series of specimens of Firebricks and Clays from Calstock, Cornwall.

Beck, F., Esq.—Specimen of fossil wood (phosphatised) from Appleton, Norfolk.

Benson, W. A. S., Esq.—Two specimens of Cone in Cone Coal.

Berry, J., Esq., M.I.M.M.—Specimens of rough and picked garnets, also Copper Ores from Northern Transvaal.

Cater, W. E., Esq.—Two polished slabs of "Verde Antico" marble.

Clarke, S. R., Esq.—A specimen of "Portland Beef."

Cresswell, C. G., Esq.—A specimen of reniform native Arsenic associated with gold quartz, from the Kapanga gold mine, New Zealand.
Portion of a trunk of *Sequoia*, and a specimen of Retinite from Bovey Tracey.

Davies, Bros., Messrs.—Series of samples of Rustic Slates.

Edwards, A. W. J., Esq.—Saline deposits from the Niger-Chad Frontier, Bornu, Nigeria.

Foster, D. F., Esq.—Echinoids and lamellibranchs from the Upper Chalk of Banstead railway-cutting.

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GEIKIE, SIR A., K.C.B., O.M., &c.—Two specimens of Geikielite from Ceylon.

GREENLY, E., ESQ.—Ordovician graptolites collected by the late Dr. Callaway, from Llanbabo, Anglesey.

HALL, LIEUT. T. C. F.—A suite of specimens from Lundy Island.

HELLYAR, W. A. S., ESQ.—Wolfram ore from the Gazeland Mine, St. Neot, Cornwall (per Mr. H. Dewey).

HIND, DR. WHEELTON, B.S., F.R.C.S.—A set of fossils from the Cayton Gill Beds (Millstone Grit) of Hazel Hill, and Clints Quarry, near Pateley Bridge.

HODGKINS, A., ESQ.—Samples of Fluorspar produced by The Grove Syndicate, Ltd.

JOHNSTON, MISS M. S.—Rock specimens from North Wales. *Labechia rotunda* Johnston, from the Wenlock Limestone of Much Wenlock.

JONES, R. M., ESQ.—Sample of sand from near Green Park, Llandegla, Wrexham.

KEAYS, REV. R. H. L.—*Cidaris clavigera* Mant. from the Gravel at Tupwood Hill, Caterham.

KING, H. H., ESQ.—Specimen of Wolfram in Pegmatite, &c.

LAKING, SIR G. F., BART., C.B., M.V.O.—A selection of specimens from the collection of the late Sir Francis Henry Laking.

LAWRENCE, E. J., ESQ.—Cyanite Fuchsite Rock.

LOUIS, D. A., ESQ., THE EXECUTORS OF THE LATE.—*Ammonites sp.* from the Upper Volgien of Kachpour near Syzran, Volga. A selection of minerals, ores and rocks.

MCGHIE & SONS, LTD., MESSRS. THOMAS.—A series of specimens illustrating the products of the Thistle Plaster Works, Newbiggin, Carlisle.

MILLS, G. R., ESQ.—Two specimens of Bunter Sandstone from Worcestershire, showing papillated structure.

MORROW-CAMPBELL, J., ESQ., M.I.M.M.—Polished specimen of gold in mispickel from Kumasi, Ashanti.

PICKERSGILL-CUNLIFFE, MISS M. H.—A series of minerals from Central Europe.

POCOCK, F. W., ESQ.—Minerals from Rhodesia.

POCOCK, LIEUT. R. W., B.SC.—Volcanic rocks, and fragments of elephant tusk, &c., from the Isle of Imbros.

RAMSDEN, R. H., ESQ.—Specimens of barytes, blende, lead and quartz from Minsterley, Shropshire.

RICHARDSON, L., ESQ., F.R.S.E.—A series of Jurassic fossils and rocks from the West of England.

RIGG, H., ESQ.—Large twinned crystal of Wolfram with quartz from the Tavoy district, Lower Burmah.

RUDLER, F. W., THE EXECUTORS OF THE LATE.—Crystals of Parisite, and Quartz crystal with moving bubble from Japan.

SHARMAN, MRS.—*Cidaris clavigera* Mant. from the Upper Chalk of Charlton, Kent.

SLADEN BEQUEST (*per* A. BELL, ESQ.).—A series of gasteropods from the Pleistocene of Blackwater, Co. Wexford.

SPRENGER, F., ESQ.—A dressed block of Penkridge Stone.

STEVENS, W. F., ESQ.—Specimens of rocks from, and sketch map of the Tannu Ola gold district, Siberia.

TEALL, SIR J. J. H., F.R.S.—Specimen of gabbro from Mount Hope, Baltimore. Series of corundum-bearing rocks from Morlaix, Brittany.

TRICKETT & SONS, MESSRS. S.—Thirteen specimens of Building Stones.

VAUGHAN-STEVENS, A., ESQ.—Samples of clay and ochre from Treven Farm, Cornwall.

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WALFORD, E. A., ESQ.—*Terebratula walfordi* Dav., *Waldheimia indentata* J. de C. Sow. from the Middle Lias of Oxfordshire; *Trigonia walfordi* Lyc. from the Inferior Oolite of Stow-on-the-Wold.

WEBBER, B. K., ESQ.—Flint with fragments of *Inoceramus*-shell from Canvey Island.

WILLIAMS, G. H., ESQ. (*per* SIR J. J. H. TEALL).—Specimen of Pyroxenite (Websterite) from Webster, North Carolina.

WILLOUGHBY, MISS.—A fossil fish (framed).

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

(*a*) SIX-INCH REFERENCE MAPS.

The following 90 standard copies of six-inch quarter-sheets have been made from the field-copies, and are available for reference:—

Berkshire, 23 S.E.; 24 S.W.

Buckinghamshire, 48 N.E., S.W., S.E.; 49 S.W.; 52 N.W., N.E., S.E.; 54 N.W., S.W.

Carmarthenshire, 44 S.W.; 51 N.W.

Hertfordshire, 43 S.W.; 47 N.W.

Kent, 1 N.E., S.E.; 7 S.E.; 15 N.E., S.E.

London, 5 S.E. (Midx. 15 S.E.); 6 S.W. (Midx. 16 S.W.), 6 S.E. (Midx. 16 S.E.); 7 S.W. (Midx. 17 S.W.), 7 S.E. (Midx. 17 S.E.); 9 N.E. (Midx. 20 N.E.), 9 S.E. (Midx. 20 S.E.); 10 N.W. (Midx. 21 N.W.), 10 N.E. (Midx. 21 N.E.); 11 N.W. (Midx. 22 N.W.), 11 N.E. (Midx. 22 N.E.); 12 N.W. (Midx. 23 N.W.), 12 S.W.; 13 N.E. (Midx. 25 N.E.); 16 N.W.

Middlesex, 10 N.W., S.W.; 20 N.W., S.W.; 25 S.E.

Pembrokeshire, 26 S.W.; 27 S.W., S.E.; 28 N.E.; 29 N.W., S.W., S.E.; 30 S.W.; 31 (whole sheet), (31A S.W. and 31c S.E.); 32 N.W., S.W., S.E.; 33 S.E.; 34 S.W.

Surrey, 1 S.E.; 2 S.W., S.E.; 3 N.W., N.E., S.W., S.E.; 6 N.E., S.E.; 7 N.W., N.E., S.W., S.E.; 8 N.W., N.E., S.W., S.E.; 12 N.E., S.W., S.E.; 13 N.W., N.E., S.W., S.E.; 14 N.W., N.E., S.W., S.E.; 18 N.W., N.E.; 19 N.W., N.E.; 20 N.W., N.E.; 21 N.W.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1914, pp. 84, text figures 3. Price 1*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. 1.—Tungsten and Manganese Ores. By H. Dewey and C. E. N. Bromehead, B.A., with contributions by T. Eastwood, A.R.C.S., G. V. Wilson, B.Sc., and R. W. Pocock, B.Sc., pp. 59, text figures 2. Price 1*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. II.—Barytes and Witherite. By R. G. Carruthers, T. Eastwood, A.R.C.S., G. V. Wilson, B.Sc., R. W. Pocock, B.Sc., and D. A. Wray, B.Sc., with contributions by H. Dewey and C. E. N. Bromehead, B.A., pp. 93, text figures 6. Price 1*s*. 6*d*.

Special Reports on the Mineral Resources of Great Britain. Vol. III.—Gypsum and Anhydrite, Celestine and Strontianite. By R. L. Sherlock, D.Sc., and B. Smith, M.A., pp. 57, text figures 2. Price 1*s*.

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The Coals of South Wales, with special reference to the origin and distribution of Anthracite. Second edition. By A. Strahan, M.A., Sc.D., LL.D., F.R.S., and W. Pollard, M.A., D.Sc., F.I.C., assisted by E. G. Radley, pp. 91, plates 10. Price 2*s.*

Geology of the Country near Lymington and Portsmouth (Explanation of Sheets 330 and 331 [Mainland]). By H. J. Osborne White, F.G.S., pp. 78, text figures 15. Price 1*s.* 6*d.*

Geology of the Country between Whitby and Scarborough (Explanation of quarter sheets 95 N.W. and 104 S.E. [New Series 35 and 44]). Second Edition. By C. Fox-Strangways, F.G.S., and G. Barrow, F.G.S., with a chapter on the palæontological classification of the local Jurassic Rocks, by S. S. Buckman, F.G.S., pp. 144, text figure 1. Price 2*s.* 6*d.*

Geology of the Country around Windsor and Chertsey (Explanation of Sheet 269). By H. Dewey, F.G.S., and C. E. N. Bromehead, B.A., F.G.S., pp. 123, plates 5, text figures 4. Price 2*s.* 6*d.*

SCOTLAND.

I.—MAPS.

(*a*) Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the office for reference:—

Argyll, 71, 72; Inverness, 1, 29 N.E., 31 N.E., S.E., 43 N.E., S.E., 116 N.E., S.W., S.E., 145 N.E.; Ross, 15, 24 N.E., S.W., S.E., 25, 40, 61; Skye, 24 N.E., S.E., 30 N.E., S.E., 36; Sutherland, 32 N.W., S.W.

Sheets formerly clean copied, but not reported as deposited, which have now been checked, revised, and deposited for reference:—

Elgin, 5, 10; Forfar, 26, 27, 28, 31, 32, 33, 34, 35, 39, 40, 41, 46; Nairn, 1, 2 with 2A, 3.

II.—MEMOIRS.

Summary of Progress for 1914. See p. 41.

The Geology of Mid Strathspey and Strathdearn, including the country between Kingussie and Grantown (Explanation of Sheet 74). By L. W. Hinxman, B.A., F.R.S.E., and E. M. Anderson, M.A., B.Sc., With contributions by J. Horne, LL.D., F.R.S., R. G. Carruthers, F.G.S., and C. B. Crampton, M.B., C.M., and a Petrographical chapter by J. S. Flett, LL.D., F.R.S., pp. 97, plates 6, text figures 9. Price 2*s.* 6*d.*

Special Reports on the Mineral Resources of Great Britain, Vols. I. and II. (*see* p. 41).

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APPENDIX I.

On a Deep Boring for Coal near Little Missenden, in Buckinghamshire.

By A. Strahan, Sc.D., LL.D., F.R.S.

This boring was commenced about the middle of the year 1913, and had been carried to a depth of 1,264 feet in September of that year, when it was abandoned.

It was situated on the eastern side of a road 3 furlongs south of Affrick's Farm on the New Series one-inch Map 255, in Latitude 51° 40′ 35″, W. Longitude 0° 41′ 45″. The road here crosses a small valley, and the elevation of the surface is 459 feet above Ordnance Datum.

The nearest deep borings in which palæozoic rocks have been reached are Calvert, 20 miles to the N.W.; Bletchley, 22 miles, nearly N.; Ware, 30 miles to E.N.E.; Turnford, 28 miles, nearly E.; Willesden and Southall, 20 and 19 miles to the S.E. The new trial, therefore, lay centrally in a broad tract not previously explored, and as a source of information of purely scientific value was useful, but in view of the fact that rocks ranging in age from pre-Cambrian to Old Red Sandstone had been encountered in the borings mentioned, was not hopeful as a search for coal.

It was commenced close below the Chalk Rock, which crops out in the sides of the valley. Down to a depth of 1,200 feet the hole was punched, and for the most part sludge only was baled out, but some specimens of clay with fossils were obtained by Mr. Pringle from lumps caught in the chisels at depths of 1,026 and 1,032½ feet. Many samples of the sludge from depths of 820 feet downwards were also examined by him. The following notes by Mr. Pringle represent all the information that could be gained respecting the Cretaceous and Oolitic Rocks.

Secondary Rocks of the Missenden Borehole.

	Depth in feet.
Top of the Middle Chalk	0
Unknown	0—820
Dark clay with small fragments of Ostrea ...	at 820 and 890
Brownish clay with fragments of Oxfordian fossils	at 1,026
Similar clay	at 1,032½
Oolitic grains, with rounded grains of quartz, became abundant and the sludge bore the appearance of ground-up limestone	at 1,046
The oolitic grains became less abundant, and the quartz grains more abundant downwards, until the sludge became a fine-grained quartz-sand...	at 1,065
Fine-grained muddy sand with very small quartz-grains...	at 1,070 to 1,098
Large oolitic grains and well-rounded quartz-grains...	at 1,103¼
Muddy sand, with some oolitic grains which apparently had been washed down from above...	at 1,107 to 1,197½

The fossils from the depths of 1,026 and 1,032½ feet include the following:—*Webbina irregularis* d'Orb., *Gryphaea sp.*, *Nucula calliope* Borissjak [?d'Orb.], *Nucula* cf. *oxfordiana* Roeder, *Belemnites sp.*, *Hecticoceras sp.* and *Taramelliceras* cf. *denticulatum*

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(Oppel) [non Ziet.]. The ammonites mentioned are indicative of the Renggeri Zone of the Middle Oxford Clay.

It is not improbable, however, that the clay had dropped, or been dragged by the chisel, from a higher part of the borehole. For the material at 1,046 feet is suggestive of an oolitic limestone in the Great Oolite Series, and it lay only 13½ feet below the level at which the specimens of clay were obtained, while at Calvert the highest oolitic limestone lay 98 feet 3 inches below the base of the Oxford Clay. The evidence is not sufficient to justify the supposition that there is attenuation or absence of any part of the sequence.

Of the strata between the depths of 1,103¼ and 1,200 feet nothing can be said, except that there was no red staining suggestive of Trias, and no material that could be attributed to Old Red Sandstone.

The Palæozoic Rocks in the Missenden Borehole.

The Palæozoic floor is believed to have been reached at a depth of 1,200 feet from the surface. At this depth drilling was substituted for punching and cores became available. The cores are 5 inches in diameter and show dips ranging from 5° to 10°. The following account of them and of their contained fossils has been drawn up by Mr. J. Pringle:—

	Thickness. ft.	in.	Depth. ft.	in.
Dark greenish-grey micaceous shale, traversed by numerous tubes (worm-burrows?)	2	6	1,202	6
Grey sandy limestone	1	0	1,203	6
Dark grey shale with thin bands of limestone...	10	0	1,213	6
Grey shelly limestone	0	3	1,213	9
Dark grey shale	0	3	1,214	0
Grey shelly limestone	0	3	1,214	3
Dark grey micaceous shale	1	9	1,216	0
„ with thin sandstones and limestones; worm-burrows in the shales	16	6	1,232	6
Grey sandy limestone	0	9	1,233	3
Dark grey sandy shale with phosphatic granules and nodules	2	9	1,236	0
Grey sandy limestone	0	8	1,236	8
Grey micaceous sandstone and dark grey shale	7	4	1,244	0
Grey sandy limestone with pebbles and phosphatic grains; numerous Fish spines and bones	1	0	1,245	0
Grey micaceous shale and grey limestone ...	1	0	1,246	0
Dark grey shaly sandstone	4	0	1,250	0
Grey sandy limestone with fish fragments ...	2	0	1,252	0
Grey micaceous shale	2	0	1,254	0
Grey micaceous shaly sandstone with thin bands of limestone with fish fragments ...	9	0	1,264	0

The evidence obtained from the cores is of a decisive character, and the occurrence of *Onchus murchisoni*? Ag. and *Onchus tenuistriatus* Ag., with other fossils characteristic of the Upper Ludlow rocks, renders the task of correlation a somewhat easy matter. All of the Palæozoic rocks brought up as cores correspond with a part of the Upper Whitecliff Beds of the Ludlow district.[1] The domi-

[1] For a description of these beds *see* Elles, G. L., and Slater, I. L., 'On the highest Silurian Rocks of the Ludlow District.' *Quart. Journ. Geol. Soc.*, vol. lxii, pp. 195–222, 1906.

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nant fossil is *Chonetes striatella* Dalm., but in addition to this brachiopod the following species occur numerously:—*Camarotoechia nucula* (J. de C. Sow.), *Bellerophon trilobatus* J. de C. Sow., *Tentaculites ornatus* J. de C. Sow., *T. tenuis* J. de C. Sow., *Holopella obsoleta* (J. de C. Sow.), and *Beyrichia* cf. *noetlingi* Reuter. About 80 per cent. of the fossils determined have been recorded from the typical sections in Shropshire.

The fossils are chiefly confined to the thin bands of limestone, some of which are almost entirely composed of fragments of *Chonetes striatella* and species of *Beyrichia*. At the depth of 1,244 feet a limestone, 1 foot in thickness, contains abundant fish-remains, and almost merits the designation of 'bone-bed.' Some of the shales, however, contain numerous infilled tubes which have been referred to worm-burrows. Lithologically, the beds at Little Missenden agree more closely with the rocks at Ludlow than with those of South Staffordshire recently described by Messrs. King and Lewis.[1]

The presence of *Orthoceras damesi* Roemer [? Krause] is worthy of note, since this rare species does not appear to have been hitherto recorded in this country. The specimen, in addition to presenting an excellent section showing the siphuncle, exhibits the fine delicate net-work on the outermost layer which is a characteristic structure of the species. It agrees closely with the figure of Roemer,[2] but is unlike the specimen figured by Krause.[3]

The following is a list of the fossils obtained from the cores:—

Crinoidal columnals
Cornulites serpularius *Schloth.*
Serpulites longissimus *Murch.*
Camarotoechia nucula (*J. de C. Sow.*)
Chonetes striatella *Dalm.*
„ sp.
Lingula lewisi *J. de C. Sow.*
„ sp.
Orbiculoidea rugata (*J. de C. Sow.*)
Orthis (Dalmanella) lunata *J. de C. Sow.*
Wilsonia wilsoni ? (*J. de C. Sow.*)
Modiolopsis *cf.* complanata *J. de C. Sow.*
Orthonota amygdalina (*J. de C. Sow.*)
„ decipiens (*McCoy*)
„ spp.
Bellerophon trilobatus *J. de C. Sow.*
Holopella gregaria (*J. de C. Sow.*)
„ obsoleta (*J. de C. Sow.*)
Murchisonia *cf.* articulata (*J. de C. Sow.*)
Tentaculites ornatus *J. de C. Sow.*
„ tenuis *J. de C. Sow.*
Orthoceras *cf.* bullatum *J. de C. Sow.*
„ damesi *Roemer* [*?Krause*]
„ ludense *J. de C. Sow.*

[1] King, W. W., and Lewis, W. J., 'The Uppermost Silurian and Old Red Sandstone of South Staffordshire.' *Geol. Mag.*, Dec. v., vol. ix, pp. 437-443, 484-491, 1912.

[2] Roemer, F., 'Lethaea Erratica' etc. *Palaeont. Abhandl.*, Band ii, Taf. xxxi, figs. 11, 12 *a* & *b*, p. 104, 1885.

[3] Krause, A. *Zeitschrift d. deutsch. geol. Gesellschaft*, Band xxix, Taf. i, figs. 11 *a* & *b*, p. 25, 1877.

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Beyrichia kloedeni *McCoy*
„ *cf.* noetlingi *Reuter*
„ spp.
Calymene sp.
Cytherellina siliqua *Jones*
Leperditia sp.
Phacops ?
Climatius ?
Onchus murchisoni ? *Ag.*
„ tenuistriatus *Ag.*
„ sp.
Fish bones

The occurrence of Ludlow Beds under this part of Buckinghamshire throws some further light on the arrangement of the Palæozoic rocks under the London Basin. All the bore-holes in and near London, from Turnford on the north to Streatham on the south, and from Southall on the west to Crossness on the east, have encountered Old Red Sandstone or Devonian. Proceeding northwards from the region thus proved, we find Ludlow at Missenden, Wenlock at Ware, Cambrian at Calvert, and pre-Cambrian at Bletchley, a succession which suggests a general southward dip. On the somewhat improbable assumption that the outcrops run with an approach to regularity, we may further suppose that the strike ranges from near Missenden to some point between the Wenlock of Ware and the Old Red Sandstone of Turnford, that is in a direction a little north of east.

The southern margin of the Old Red Sandstone tract is wholly unknown. That Silurian rocks underlie the Secondary strata to the east and east-south-east of London has been proved at Cliffe, Bobbing and Chilham, and that these are followed still further east by a syncline with a trend slightly west of north and a pitch to the south, and containing Carboniferous rocks, is known from the borings in Kent. In a north-easterly direction the Palæozoic floor has not yet been proved between London and the borings at Weeley and Stutton near Harwich, and in a southerly direction nothing is known of it south of Streatham. Clearly, therefore, it is not yet possible to define the form or the trend of the London Old Red syncline.

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APPENDIX II.

Catalogue of Types and Figured Specimens of British CRETACEOUS GASTEROPODA preserved in the Museum of Practical Geology, London.

By H. A. Allen, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species or variety. The figures in brackets, [7009], correspond to the number in the Museum Register; those preceded by "GS." refer to specimens formerly in the collection of the Geological Society.

The following abbreviations are employed:—

Geol. Mag.: The Geological Magazine, London.
Trans. G. S.: Transactions of the Geological Society of London.
Q.J.G.S.: Quarterly Journal of the Geological Society of London.

(The dates quoted refer to year of issue only.)

Aporrhais dupiniana (d'Orbigny).
J. S. Gardner, Geol. Mag., vol. ii., 1875, pl. vii., f. 13, p. 297.
Lower Greensand. [28243] Sandown.

Aporrhais elongata (J. de C. Sowerby).
J. S. Gardner. Geol. Mag., vol. ii., 1875, pl. v., f. 3, p. 126.
Gault. [1729] Folkestone.

Aporrhais griffithsi Gardner. **T.**
J. S. Gardner, Geol. Mag., vol. ii., 1875, pl. iii., f. 14, p. 55.
Gault. [1728] Folkestone.

Aporrhais histochila Gardner. **T.**
J. S. Gardner, Geol. Mag., vol. ii., 1875, pl. vii., f. 5, p. 294.
Upper Greensand. [28244] Devizes.

Aporrhais robinaldina (d'Orb.).
J. S. Gardner, Geol. Mag., vol. ii., 1875, pl. vii., f. 12, p. 295.
Speeton Clay. [28242] Speeton.

Avellana pulchella Price. **T.**
F. G. H. Price, Q.J.G.S., vol. xxx., 1874, pl. xxv., figs. 4, 5, p. 355.
Gault (bed vii). [1722, 1722A] Folkestone.

Buccinum gaultinum d'Orb.
F. G. H. Price, Q.J.G.S., vol. xxx., 1874, pl. xxv., figs. 1, 2, p. 349.
Gault. [1716, 28264] Folkestone.

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Calyptraea grayana Tate. **T.**

R. Tate, Q.J.G.S., vol. xxi., 1865, pl. iii., f. 8, p. 38. Refigured J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. vii., f. 25, p. 201.
Upper Chalk (White Limestone). [27111] Kilcorig, Lisburn.

Cerithium lallierianum Forbes.

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 10, p. 352.
Lower Greensand. [GS. 2277] Atherfield.

Cerithium neocomiense Forbes.

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 8, p. 351.
Lower Greensand. [GS. 2272] Atherfield.

Cerithium phillipsi Forbes.

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 12, p. 352.
Lower Greensand. [GS. 2267] Atherfield.

Cerithium turriculatum Forbes. **T.**

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 7a, b, p. 352.
Lower Greensand. [GS. 2253, 2255] Atherfield.

Cinulia catenata Tate. **T.**

R. Tate, Q.J.G.S., vol. xxi., 1865, pl. iii., f. 4, p. 38.
Upper Chalk (White Limestone). [27967, 27968] Kilcorig, Lisburn.

Crucibulum giganteum Gardner.

J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. vii., figs. 3, 4, p. 203.
Lower Greensand. [27110] Shanklin.

Dentalium coelatulum Baily. **T.**

W. H. Baily, Q.J.G.S., vol. xiii., 1857, pl. ii., f. 8, p. 87.
Upper Greensand. [28260] Moreseat, Aberdeenshire.

Dentalium cylindricum J. Sow.

E. Forbes, Q.J.G.S., vol. i., 1845, p. 346.
Lower Greensand. [GS. 2233] Atherfield.
J. S. Gardner, Q.J.G.S., vol. xxxiv., 1878, pl. iii., f. 21, p. 61.
Greensand. [28263] Blackdown.

Dentalium divisiense Gardner. **T.**

J. S. Gardner, Q.J.G.S., vol. xxxiv., 1878, pl. iii., f. 15, p. 60.
Upper Greensand. [28262] Devizes.

Dentalium medium J. de C. Sow.

J. S. Gardner, Q.J.G.S., vol. xxxiv., 1878, pl. iii., f. 14, p. 59.
Greensand. [28261] Blackdown.

Dimorphosoma ancylochila Gardner. **T.**

J. S Gardner, Geol. Mag., vol. ii., 1875, pl. xii., f. 2, p. 397.
Lower Greensand. [28239] Atherfield.

Dimorphosoma kinclispira Gardner. **T.**

J. S. Gardner, Geol. Mag., vol. ii., 1875, pl. xii., f. 1, p. 396.
Lower Greensand. [28240, 28241] Atherfield.

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Emarginula gresslyi Pict. & Camp.

J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. viii., f. 18, p. 197.
Upper Greensand [27113] Devizes.
J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. viii., f. 16, 17, p. 198.
Chloritic Marl. [27117] Cheddington.

Emarginula neocomiensis d'Orb.

E. Forbes, Q.J.G.S., vol. i., 1845, p. 346.
Lower Greensand. [GS. 2229] Atherfield.
J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. viii., figs. 5-6, p. 196.
Lower Greensand. [3038, 27112] Atherfield.

Emarginula sanctaecatherinae Passy.

J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. viii., figs. 21, 22, p. 198.
Chloritic Marl. [27114] White Nore.

Fusus smithi J. de C. Sowerby.

A. J. Jukes Browne, Q.J.G.S., vol. xxxi., 1875, pl. xiv., f. 6, p. 291.
Gault. [GS. 1709A] Copt Point, Folkestone.

Hipponyx dixoni Deshayes.

J. S. Gardner, Q.J.G.S., vol. xxxiii., 1877, pl. ix., figs. 12, 13, p. 204.
Upper Chalk. [27115, 27116] Bromley.

Natica canaliculata J. de C. Sow. **T.**

J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., 1836, pl. xi., f. 12c, p. 336.
Gault. [GS. 1708] Copt Point, Folkestone.

Natica obliqua Price. **T.**

F. G. H. Price, Q.J.G.S., vol. xxx., 1874, pl. xxv., f. 3, p. 356.
Gault (Bed iv). [1681] Folkestone.

Natica rotundata Forbes.

E. Forbes, Q.J.G.S., vol. i., 1845, p. 346.
Lower Greensand. [GS. 2268] Atherfield.

? ? Pileopsis.

E. Forbes, Q.J.G.S., vol. i., 1845, p. 346.
Lower Greensand. [GS. 2232] Parham.

Pleurotomaria anstedi Forbes. **T.**

E. Forbes, Q.J.G.S., vol. i., 1845, pl. v., f. 1, p. 349.
Lower Greensand. [GS. 2235] Nutfield, nr. Reigate.

Pterocera fittoni Forbes. **T.**

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 6, p. 351.
Lower Greensand. [GS. 2283] Atherfield.

Pyrula brighti J. de C. Sow. **T.**

J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., 1836, pl. xviii., f. 21, p. 344.
Greensand. [GS. 1620] Blackdown.

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Rostellaria glabra Forbes. **T.**

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 5, p. 350.
Lower Greensand. [GS. 2281, 2293] Atherfield.

Rostellaria maxima Price. **T.**

F. G. H. Price, Geol. Mag., vol. x., 1873, pl. vi., p. 97.
Upper Gault. [1731] Copt Point, Folkestone.

Scalaria albaecretae Tate. **T.**

R. Tate, Q.J.G.S., vol. xxi., 1865, pl. iii., f. 6, p. 38.
Upper Chalk (White Limestone). [28245] Kilcorig, Lisburn.

Scalaria canaliculata d'Orb.

J. S. Gardner, Geol. Mag., vol. iii., 1876, pl. iii., f. 5, 5a, p. 107.
Lower Greensand (Crackers). [28247, 28248] Atherfield.

Scalaria fittoni Gardner. **T.**

J. S. Gardner, Geol. Mag., vol. iii., 1876, pl. iii., f. 11, p. 108.
Greensand. [28246] Blackdown.

Scalaria?

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 4, p. 349.
Lower Greensand. [GS. 2251] Atherfield.

? Solarium benstedi Forbes. **T.**

E. Forbes, Q.J.G.S., vol. i., 1845, p. 349.
Lower Greensand. [GS. 2257] Maidstone.

Solarium conoideum J. Sow.

J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., 1836, pl. xi., f. 14, p. 336.
Gault. [GS. 1688] Folkestone.

Tornatella affinis J. de C. Sow.

J. de C. Sowerby, Trans. G. S., Ser. 2, vol. iv., 1836, pl. xviii., f. 9, p. 343.
Greensand. [28347] Blackdown.

Tornatella marginata (Deshayes).

E. Forbes, Q.J.G.S., vol. i., 1845, p. 357.
Lower Greensand. [GS. 2227, 2228] Atherfield.

Trochus albensis Forbes.

E. Forbes, Q.J.G.S., vol. i., 1845, p. 347.
Lower Greensand. [GS. 2244] Peasemarsh.

Trochus decussatus Forbes.

E. Forbes, Q.J.G.S., vol. i., p. 348.
Lower Greensand. [GS. 2231] Maidstone.

Turbo munitus Forbes. **T.**

E. Forbes, Q.J.G.S., vol. i., 1845, pl. iv., f. 2, p. 348.
Lower Greensand. [GS. 2245] Peasemarsh.

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The following lists of British type-fossils have been published in the "Summary of Progress," and *issued* in the years stated:—

Eocene and Oligocene	1900.
Pliocene, Pleistocene and Devonian	1901.
Phyllocarida and Palæozoic Echinodermata	1902.
Rhætic, Lias, and Inferior Oolite Gasteropoda	1903.
Great Oolite, Cornbrash, and Corallian Gasteropoda ...	1904.
Rhætic and Lias Lamellibranchiata	1905.
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SUMMARY OF PROGRESS

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FOR 1916.

I.—*INTRODUCTION.*

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

The continuance of the War and an increase in the number of special investigations which are required in connection with it and with industrial policy after it is over, have necessitated a temporary suspension in all districts of the normal work upon which the Survey has been engaged of late years. Already, in 1915, enquiries respecting British resources of a number of minerals of economic value had absorbed much of the time of the staff. As a result, and partly also through an increasing difficulty in engraving and colour-printing maps, it became clear in 1916 that the Survey could best serve the interests of the country by concentrating attention upon such matters, and temporarily suspending all normal field-surveying. Thus the discontinuance of field-work in the London and South-Eastern district in 1915 was followed by discontinuance in the districts of Denbighshire, Shropshire, Staffordshire and Warwickshire, in 1916. In the year 1915 publication of a series of 'Special Reports on the Mineral Resources of Great Britain' was commenced. Similarly, in Scotland, the energies of the staff were directed to continuing the revision of coalfields in preference to carrying on the primary six-inch survey in the Highlands, and eventually, as regards field-work, to dealing with various enquiries arising out of the War, to the collecting of information for the 'Special Reports' and to the examination of a district in which there seemed to be a promising source of iron-ore awaiting development.

The examination of boreholes in progress could not however be suspended, either in England or Scotland, without risking the loss of valuable information.

The initiation of the series of 'Special Reports' referred to was briefly recorded in the Summary of Progress for 1915, p. 1. During that year the first three volumes of the series were published, and in 1916 these were followed by Vols. 4 and 5.

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During 1916 also the field-work connected with the wide subject of refractory materials was completed, an extensive series of specimens was collected, and the petrological and chemical examination of them was put in hand. At the same time an enquiry into the resources of iron-ore in Britain was commenced. Second editions of three of the volumes were required before the end of the year.

The scope of these publications, and the nature of the work required for their preparation, are indicated by the following extract from the preface of Vol. 1:—

"The method of occurrence and the exploitation of minerals in Britain have already been described by the Geological Survey in various District Memoirs and Explanations of the sheets of the one-inch maps, but in each case the information relates only to the areas dealt with in the Memoir. The Iron Ores of Great Britain, published in 1856–62, the more recent Handbooks to the Collections of Gemstones, of Clays and of Pottery in the Museum of Practical Geology, the Memoirs on the Oil Shales, and on the character of the Coals of South Wales, are cases in which the economic applications of geology have formed the subject of separate publications. As regards other minerals the records are either scattered through a number of publications, or are not forthcoming in districts for which no Memoir has been prepared.

It was clearly desirable therefore to assemble all the information, to bring it up to date by an examination of the mines, quarries, etc., from which economic minerals are or have been produced, and to make it available in a convenient form.

The present publication is the first of a series in which these objects are being kept in view. In each volume the characters, sources, uses and methods of preparation of the minerals under consideration will be described in an Introductory Chapter. This will be followed by an account of each of the mines or quarries from which the minerals are or have been produced, together with notes on some occurrences which have not been commercially exploited. The principal points dealt with in the description of the mines are the situation, history and extent of the workings, and one of the objects has been to show, among other things, where minerals of value have been left in old workings, as well as where they may be expected to occur in untouched ground.

At the same time brief notes are given on possible obstacles to further development which may arise from heavy water, difficulties in transport, or other causes."

In addition to forming a record of the particulars referred to in the above extract, these publications illustrate the variations in value of raw mineral products according to the demand created for them by new industries, or by new applications in old industries. In the first volume it is shown that ore of tungsten, which is now in keen demand, especially for the manufacture of hard steel, was formerly a waste-product, and that its prevalence in some of the tin-mines led to their being closed. Similarly barytes, dealt with in Volume 2, is now raised largely from old lead-mines, in which it was left as not worth extraction unless it contained a payable quantity of galena. Fluorspar, the subject of Volume 3, is also being raised from old lead-mines, and in some parts of the country is being picked out of the waste-heaps. In several cases barytes and fluorspar have taken the first place as the products of the mines, while galena has become a by-product, and probably would have been no longer raised had it not been associated with an accessory mineral of value. Sandstones, regarded a few years ago as

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useless save for rough building or inferior road-metal, have come into demand for refractory purposes, and sands are finding a variety of uses. The lesson is impressed that exhaustive investigation should be made of all rocks and minerals, irrespective of their commercial value at the moment.

As regards resources in Britain, the result of the investigation has proved satisfactory in the case of some of the minerals so far dealt with. Of such products as barytes and witherite, gypsum and anhydrite, fluorspar, sandstones and sands, the reserves of all except a few of the finest and most exceptional qualities, are ample. On the other hand the occurrences of tungsten-ores, celestine, graphite, molybdenite, chromite, steatite and diatomite are strictly limited, while the cost of home-production of phosphatic minerals rendered them unfit to compete commercially with foreign material. The production of the finest qualities of such materials as barytes, fluorspar, calc-spar and glass-sands is partly dependent upon the care which is devoted to selecting and preparing them, which itself depends upon the price obtainable. In some cases, such as sands for glass-making and other purposes, the relative cost of transport by rail or water becomes a determining factor in the use of British or foreign material. Home-resources of all but the exceptional qualities, however abundant they may be, will not be fully utilised so long as they cost the manufacturer more than the foreign material.

The distribution of the economic minerals is fully set out in the 'Special Reports.' That, so far as regards those deposited from solution under normal conditions (metasomatic replacement), it was determined by local circumstances is clear, but it seldom appears what those circumstances were. Barytes, for example, is the principal spar in veins in Carboniferous Limestone in Teesdale, while fluorspar is the principal spar in veins in the same formation in Weardale. Derbyshire is a well-known centre for fluorspar and barytes in Carboniferous Limestone, yet in Flintshire that formation yields little of either mineral. Moreover, in Derbyshire, the fluorspar is more or less confined to the eastern margin of the limestone-tract. It tends, also, to occur in the uppermost beds of the limestone, and to be replaced downwards by barytes and calcite.

Similarly the ores of lead and zinc are concentrated within certain districts, irrespective of the fact that the strata which are productive within those districts extend beyond them, apparently under equally favourable circumstances. This observation applies equally to the Carboniferous Limestone and to the Lower Palæozoic rocks. In both, the ore-fields are capable of a more or less precise definition, but the reason of their being limited and situated where they are is not known.

The distribution of quartz as an infilling of veins is less difficult of explanation. It frequently shows a connection with the distribution of the more siliceous rocks through which the veins pass, and the inference follows that the siliceous vein-stuff has been derived more or less directly from the neighbouring country-rock. This explanation is not available in the case of

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such minerals as barytes and fluorspar, which must have been derived from some more distant sources. That different sources were laid under contribution for vein-fillings at different times is proved by such a case as that which has been observed in Flintshire. The east-and-west veins yield a galena in which silver exists in payable quantity, and zinc-blende; the north-and-south veins, which appear to be of later date, contain galena almost devoid of silver but show traces of copper, and yield no zinc-blende. The area of productiveness is nevertheless the same for both classes of vein. The original source of the mineralising solutions is known in none of the cases mentioned, but it is to be noted that the waters appear to have penetrated from above downwards, and that all the ingredients of vein-products in the Carboniferous Limestone have been recorded in Coal Measure waters.

In the Lower Palæozoic rocks the occurrences of barytes in and near Shropshire, of lead-ores at Leadhills and Wanlockhead, in Scotland, are examples among many that could be quoted, of concentrations of minerals and ores in certain definable areas. That the dimensions of a vein may be dependent upon the capability of the rock it traverses to maintain an open fissure, is obvious, but these and other conditions appear to exist as fully outside the areas to which the ores are confined as within them.

The distribution of bedded minerals and ores is no less difficult to explain. In the Keuper Marl gypsum-deposits are interbedded at approximately the same horizon throughout a considerable part of the country, yet in one limited area in Gloucestershire and Somerset sulphate of strontia takes the place of, or has been crystallised out with the sulphate of lime, as described in Volume 3. Again, the reason for the localisation of such a deposit as that of carbonate and silicate of manganese, described in Volume 1, which is interstratified in the lower part of the Cambrian rocks of North Wales, is still to seek. That deposition of manganese ores is not unknown elsewhere at about the same horizon does not explain the exceptional concentration which took place in Merioneth.

The raw materials which are used in the manufacture of refractory products and which will form the subject of the next volume of the 'Special Reports,' come under a different category. Those which have engaged the attention of the staff in 1916 include quartzites, quartzitic sandstones, ganisters, sands and siliceous clays (fireclays). All these occur as beds in the series of sedimentary formations, and are accessible at their outcrops for determination of their characters, thickness and range. They exist in great quantity and variety in Britain, several of them in one part or another of the Carboniferous system. With the exception of dolomite they all fall under the description of acid refractories. Dolomite is abundant in this country, but other basic refractories are imported.

The silica-brick was first manufactured in 1822 at Dinas, in South Wales, though the raw material had been used in furnaces in copper-works several years before. The method, which

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was long kept secret, consisted of mixing silica-rock, crushed or naturally disintegrated, with about one per cent. of lime, enough water to make it coherent, moulding, drying and firing.[1] The Dinas silica-rock is obtained from the basal grit of the Millstone Grit.

In Yorkshire the outcrops of the sandstones and shales which compose the Millstone Grit were laid down upon the six-inch maps many years ago. These maps have now become the chief guide to the laying-out of works for the production of silica-rock.

Refractory sand of high silica percentage, used in large quantities for furnace-hearths and other purposes in the steel industry, was obtained before the war principally from Holland and Belgium. Some British sands occurring mainly in the Lower Greensand and Oolitic formations are found to be suitable for the purposes. The chief resources have been investigated during the year by Mr. G. W. Lamplugh in East Yorkshire, Norfolk, Bedfordshire and Buckinghamshire.

In Scotland the silica-brick industry was started about the year 1876. Flints from Antrim, from the Thames, and from the North of France were used, with a bonding material of plastic clay from South Wales, and until recently little inquiry had been made for Scottish materials. Ganisters and fireclays are now worked extensively, especially in the Central Valley, but it is doubtful whether any of these are equal in quality to the best English ganister. Several rocks not now worked, including sandstones and ganisters in the Lower Carboniferous groups and quartzites in the older formations, have been examined and appear likely to give good results.

For hearth-sand material imported from Belgium was used in Scotland almost exclusively, but various sandstones are now ground, and, in addition to Dutch sand, are serving as substitutes for the Belgian material.

II.—FIELD WORK.

In the following brief summary of the results of the field-work of 1916, it will be shown that the raw materials now in use for the manufacture of silica-bricks and other refractory products occur in great variety in several formations and are distributed through a large part of Britain. For their investigation the country was divided into:—

(1) The North-East of England, with Derbyshire, Yorkshire (West Riding), Nottinghamshire, Leicestershire and Warwickshire, Lincolnshire.

W. Gibson, D.Sc., District Geologist.
C. B. Wedd, B.A.
R. L. Sherlock, D.Sc., A.R.S.M. } Geologists

[1] Percy, 'Metallurgy,' 1875, p. 146.

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(2) Cumberland, Yorkshire (Ingleton Coalfield), Lancashire, Cheshire and North Staffordshire, Denbighshire and Flintshire, Anglesey, Shropshire, Worcestershire, South Staffordshire, Gloucestershire, South Wales and Monmouthshire, Cornwall and Devon.

T. C. Cantrill, B.Sc., District Geologist.
H. Dewey. } Geologists.
B. Smith, M.A. }
J. Pringle. Assistant Palæontologist.

In both Districts (1) and (2) Mr. Howe visited the principal steel works and collected information as to the trade requirements as regards refractories, and the sources of the raw materials. Mr. Pringle assisted in the examination of the Forest of Dean and of the South Wales Coalfield.

(3) Scotland.

Investigation of refractory materials.

L. W. Hinxman, B.A., District Geologist.
M. Macgregor, M.A. } Geologists.
G. V. Wilson, B.Sc. }

The Dalry Ironstone Field, Ayrshire.

C. T. Clough, M.A., LL.D., District Geologist.
C. H. Dinham, B.A. } Geologists.
G. V. Wilson, B.Sc. }

(1) The North-east of England, with Derbyshire, Yorkshire (West Riding), Nottinghamshire, Leicestershire and Warwickshire, Lincolnshire.

THE NORTH-EAST OF ENGLAND (NORTHUMBERLAND, DURHAM AND NORTH YORKSHIRE).

Silica- and ganister-bricks are manufactured somewhat extensively. Fireclay bricks are produced in large quantity, but they are not, as a rule, of a highly refractory character. Some clays, however, furnish firebricks suitable for the outer parts of furnaces. Magnesite-brick is made in comparatively small quantity from imported material, and chrome-brick in still less quantity. Several refractory sands for the purposes of iron- and steel-works are obtained in the district; but those most used are brought from distant parts of England or imported from abroad.

Ganisters and silica-rocks.—About 15 different beds of ganister and silica-rock are used for making refractory bricks. These beds range from the upper part of the Carboniferous Limestone Series (Calcareous Group) upwards into the Lower Coal Measures, while one or two are worked in the Oolites of North Cleveland. None are associated with workable coal-seams.

There is an abundant supply of these materials, but limited

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for practical purposes to such areas as afford transport facilities, Weardale being the chief source. At present, however, dearth of labour tends to counteract this abundance.

Few of these rock-beds are worked at more than one or two localities, and other beds of silica-rock could doubtless be found in the district.

Fireclays.—Firebrick is made from several good fireclays in the Lower Coal Measures below the Brockwell Coal and in the lower part of the Middle Coal Measures, the clays for the most part being associated with coals raised at the collieries. Some fireclay is obtained also from the upper part of the Carboniferous Limestone Series.

Firebrick is often made only for the sake of utilising a waste product of coal-mining. An abundant supply of clay is assured so long as the associated coal-seams are worked, and it is likely that other fireclays might be used.

Several moulding sands of Permian, Oolitic and Glacial ages are obtained in this district.

The dolomite used is obtained from a small area near Coxhoe. Its occurrence in the Permian Limestone of County Durham is capricious.

YORKSHIRE (WEST RIDING).

For variety and maximum of output of refractory goods the West Riding of Yorkshire stands pre-eminent. The bulk of the raw material is obtained from the lower part (Ganister Group) of the local Lower Coal Measures. Sheffield may be regarded as the centre of the silica-brick industry, and Leeds, Huddersfield and Halifax of firebrick.

Not only are there ample reserves in the areas at present worked, but there are many others still untouched. It should be borne in mind, however, that in passing northwards from Sheffield, the ganister below the Hard Mine Coal gradually changes its character, and over the northern part of the coal-field is more often a siliceous clay than a ganister of the Sheffield type. On the other hand the clays of the Lower Coal Measures become more regular in composition and the sandstone bands more siliceous and less felspathic. The Bunter beds furnish moulding sands, notably near Heck.

DERBYSHIRE.

No great quantity of ganister and silica-rock is raised in Derbyshire. The few rocks of these types that are used are of Coal Measure or rarely of Millstone Grit age. The Sheffield ganister (below the Hard Mine Coal of Yorkshire and Alton Coal of Derbyshire) is worked at wide intervals and could probably be worked more extensively as far south as Ambergate, southward of which it passes into fireclay. It is present in the north-west of the county, but seems not to have been tried. No other ganisters or silica-rocks are worked south of the neighbourhood of Ambergate.

Comparatively little fireclay is used for refractory purposes.

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A bed underlying the Sheffield ganister is used locally in the manufacture of ganister-brick, as is the under-clay of the Deep Hard Coal (Middle Coal Measures), with admixture of ganister sand, for making coke-oven bricks, and alone for "botting" blast furnaces.

The pockets of sand and clay which occur in the Carboniferous Limestone at numerous points in the elevated tract between Alsop Moor, Brassington and Parsley Hay are being actively worked mainly for the production of siliceous firebrick. The white or pale-grey argillaceous sands are also distributed in bulk to steelworks. Occasionally some of the more plastic white sandy clays are picked out and supplied to makers of stoneware and similar goods. In normal times it might be worth while to pay more attention to these clays for special purposes. There are large reserves of the sand and clay in this district. The material in similar pockets on the Weaver Hills in Staffordshire exhibits clearer evidence of Triassic origin than that on the Derbyshire side; it is used for the manufacture of siliceous firebricks at Oakmoor.

Preparations are being made to work the large mass of dolomitised Carboniferous Limestone at Harboro' Rocks (near Brassington), and in the immediate neighbourhood as a source of dolomite. The reserves are very large and the quality is reported to be good.

NOTTINGHAMSHIRE.

Although the dolomitic part of the Permian Formation forms a broad and continuous outcrop from near Nottingham northwards, it is only in a few places, as at Steetley, near the northern border, that it is used as a refractory material. The lower part of the Bunter formation is a well-known source of moulding sands at Worksop, Mansfield and near Nottingham; the upper part is used at Retford.

LEICESTERSHIRE, WARWICKSHIRE.

The only important refractory material in Leicestershire is a fireclay in the upper part of the Middle Coal Measures. This fireclay, which is associated with others not used for refractory purposes, provides both first-class firebrick and crucible clay. The crucible clay is regarded as of better quality when mined. Both the manufactured firebrick and the raw crucible clay are supplied extensively to the Sheffield, the northern and other districts. Reserves are abundant.

The Hartshill quartzites of the Nuneaton District were examined as a possible source of a silica-rock.

LINCOLNSHIRE.

Sandy clays of the Upper Estuarine Series are employed at Stamford as a basis for the manufacture of general fireclay-goods and gas-retorts.

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(2) Cumberland, Yorkshire (Ingleton Coalfield), Lancashire, Cheshire and North Staffordshire, Denbighshire and Flintshire, Anglesey, Shropshire, Worcestershire, South Staffordshire, Gloucestershire, South Wales and Monmouthshire, Cornwall and Devon.

CUMBERLAND.

Certain fireclays in the Lower and Middle Coal Measures are mined by several firms for making firebricks, furnace-blocks and stove-bricks, tuyeres for Bessemer converters, sleeves, stoppers, nozzles, and bricks for coke-ovens. The output is chiefly absorbed by steel and iron firms in Cumberland and Lancashire.

Highly siliceous fireclay, ganister and millstone grit is made up into ganister-compound. No silica-brick is produced in this coalfield.

Pig-bed and casting-sands are dug from local Glacial and sea-sands at Harrington and Workington.

YORKSHIRE (INGLETON COALFIELD).

No fireclays are raised in this field for making refractory goods; but certain under-clays are suitable for the manufacture of stone jars and flower-pots.

At Bentham a soft Millstone Grit is crushed for pig-bed sand, and a Glacial deposit is dug for moulding.

LANCASHIRE (FURNESS).

In the Furness district steel-moulding sand, occurring in pockets of hæmatite at the Park Mine, near Askham, was examined and sampled. Its value lies in the fact that it comes clean away from the casting and can be used for intricate work. Similar sand, occurring under slightly different conditions, is used for lining steel-converters. Reserves are large, and the output could be easily increased.

The sand is described by Mr. Smith as occurring in pockets (Fig. 1) in the surface of a platform of Carboniferous Limestone, which is thickly covered by boulder-clay.[1] The limestone is faulted against Skiddaw Slate on the east, and towards the south forms a steep face against which the St. Bees Sandstone (Trias) is banked. It dips south-westwards and the pockets are more or less arranged in lines in the direction of dip.

[1] These pockets are described by J. D. Kendall in 'The Iron Ores of Great Britain and Ireland,' 1893, pp. 98, 99 and 309.

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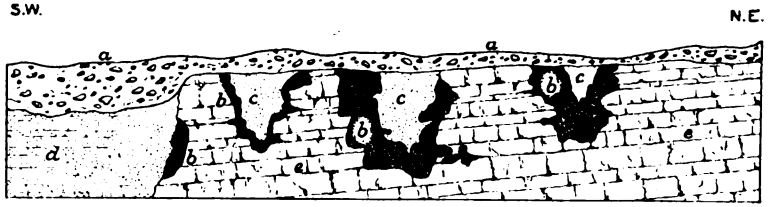
Fig. 1.—Section illustrating the occurrence of steel-moulding sands at Park Mines, Askham-in-Furness.



a. Boulder-clay. *b*. Hæmatite.
c. Sand in pockets. *d*. Trias (St. Bees Sandstone).
e. Carboniferous Limestone.

The pockets are oval to circular in plan and steep-sided. Downwards they diminish in size, often to sharp, funnel-like terminations. Their outlines, however, are most irregular, both in plan and section. A large pocket would measure about 80 fathoms in depth and 150 fathoms in greatest diameter.

They contain an outer layer of hæmatite which shows an obvious relationship in form to the walls of the pocket. Within this layer there occurs an almost continuous lining of reddish clay, varying from 6 inches to 6 feet in thickness. The central part of the pocket is filled with loose sand, with small rounded fragments or large irregular lumps of pale-grey friable stratified sandstone, all mixed confusedly together. The fragments contain occasional ferruginous, micaceous, or loamy layers and galls of clay. Near the Silurian area the pockets contain no sand; but farther from it and nearer to the red sandstone area sand gradually comes to occupy a larger part of the pocket than the ore. Both the sand and the lumps of sandstone are such as may have been derived from the St. Bees Sandstone; no other materials occur. Within 30 feet of the limestone-face referred to above, the St. Bees Sandstone is in the same fragmentary state as the material in the pockets.

The sand and the lumps of sandstone, but not the clay-lining, are crushed and mixed for use.

Pig-bed sand is obtained from Glacial deposits at Parrock Hall, north of Barrow-in-Furness; and crushed red sand from Hawcoat is used for foundry work.

Lancashire (cont.), Cheshire and North Staffordshire.

Fireclays in the Millstone Grit, and in the Lower, Middle and Upper Coal Measures, are used for the manufacture of fire-resisting goods. The industry is not centralized about any one town, but is carried on at a number of widely separated localities. Works have been visited in the following districts:—Macclesfield, Stockport, Ashton-under-Lyne, Oldham, and Bury; Bolton, Wigan and St. Helens; Blackburn and Burnley. The Lower Mountain (or Ganister) Mine Fireclay in the Lower Coal Measures is the bed chiefly used for fire-resisting goods. Other clays in the Coal Measures, and some in the Millstone Grit, have proved as a rule to be more suitable for sanitary, glazed,

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and acid-resisting wares. The so-called ganister frequently associated with the Lower Mountain Mine Fireclay is a siliceous fireclay and not a true ganister.

The reserves of fireclay are ample for present requirements and prospective developments, though a recent extension of the long-wall method of mining the coal has somewhat curtailed the output of the underclays.

The goods produced are common firebricks, and all kinds of boiler-seatings, furnace-blocks, destructor-blocks, cupola-blocks, linings for oil-furnaces, coke-oven bricks, hot-blast stove-bricks, sleeves, stoppers and nozzles, ladle-bricks, acid-resisting goods, and gas-retorts. Ground ganister is supplied to the local iron and steel works.

Moulding-sand and sand for forge-furnaces is obtained by crushing some of the siliceous sandstones in the Millstone Grit and Coal Measures; while finer varieties are obtained from the Bunter sandstones and from the Glacial and Recent deposits. Of all these there are large reserves.

Between Mow Cop and the northern end of Congleton Edge, on the Cheshire side, the siliceous sandstones or 'crowstones' of the Pendleside Series crop out from beneath the Millstone Grit and are being worked with the accompanying shales for ground ganister; the rock is also exported to other parts of the country for making silica-brick. The same sandstone is worked at Gun Hill, near Leek, for making silica-brick at Burslem. The reserves are considerable in both areas, and there are large supplies available farther north about Bosley Minn and Sutton Common, south of Macclesfield.

The clays extensively dug in the upper part of the Middle Coal Measures of North Staffordshire are used chiefly in connection with the pottery-industry.

DENBIGHSHIRE AND FLINTSHIRE.

At the southern end of this coal district the dolomite-deposits of Porth-y-waen, near Oswestry, were investigated. The rock belongs to the Carboniferous Limestone Series and is largely worked as a source of dolomite for use in the basic process of steel-making.

Farther north, near Ruabon and Wrexham, fire-resisting goods are manufactured from fireclays in the Coal Measures. The chief output, before the war, was in sanitary ware and glazed goods.

Silica-bricks are being made by an increasing number of firms from the quartzites and sandstones of the Cefn-y-fedw Series ('Millstone Grit') and from a ganister in the Coal Measures.

At Buckley some peculiar and variable fireclays at the top of the Middle Coal Measures are used mainly for acid-resisting bricks; but there is now almost as great an output of 'brindled' and white fire-resisting goods, of high strength and resistance to abrasion.

Silica-bricks are now made by one firm from siliceous beds in the Buckley Group.

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ANGLESEY.

In Anglesey, siliceous refractory materials are raised at Holyhead Mountain and at Ty-du, near Porth-wen (2½ miles W.N.W. of Amlwch). The rock at Holyhead Mountain is a quartzite, probably of pre-Cambrian age, and is capable of yielding inexhaustible supplies of the raw material. The best quality is used for the manufacture of silica-bricks; other grades are ground for ganister compound, for steel-moulding sand and hearth-sand, and for steel-moulder's paint.

The quartzite at Ty-du is to be used for similar products.

SHROPSHIRE.

In Coalbrookdale the fireclay, which is the chief refractory material, is obtained from several beds in the Middle or Productive Coal Measures, and is raised by about ten firms, mainly for the manufacture of common firebricks and saggers for use in the local potteries. Several firms engaged in the iron and steel industries make their own refractory goods.

There is apparently no shortage of raw material.

One steel and iron firm manufacture silica-bricks for their own use from a local sandstone.

Moulding-sand is obtained from the Bunter and from Glacial deposits.

Quarries in the Stiperstones Quartzite (Arenig) at Pontesbury and Granham's Moor were sampled with a view of ascertaining whether the stone can be used as a source of refractory sand. There is no lack of the raw material.

WORCESTERSHIRE.

The Lickey Quartzite of Cambrian age was sampled, as this stone has been used as a source of silica in the manufacture of certain firebricks in the Stourbridge district. There are ample reserves between Barnt Green and Rubery, where the rock is largely quarried for road-stone.

SOUTH STAFFORDSHIRE.

The chief refractory material raised is fireclay, and the manufacture of fireclay goods is concentrated in the Stourbridge district, on the borders of Staffordshire and Worcestershire. There are about six beds of fireclay of first quality and several others of inferior grade, all of which occur in the Middle or Productive Coal Measures. From these clays are produced all varieties of fireclay goods, such as firebricks of various shapes and sizes, gas-retorts, blast-furnace lining-blocks, bricks for hot-blast stoves, boiler seating-blocks, flue-covers, bricks for muffle-kilns, coke-oven bricks, glass-house tank-blocks and glass-house pots. Clay for crucibles is sold.

There appears to be no shortage of the raw material, though in some parts of the district the underground water is rising and flooding the deeper workings, and unless some comprehensive drainage scheme is adopted, there is a prospect of some of the mines being soon forced to close down.

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Common red moulding-sand is extensively raised from the Upper Mottled Sandstone (Bunter) between Stourbridge and Wolverhampton, but no highly refractory sand was met with.

GLOUCESTERSHIRE (FOREST OF DEAN).

Only one firm is engaged in the manufacture of firebrick goods. These are produced from some sandstones at the top of the Millstone Grit near Coleford, and appear to be intermediate between firebrick and silica-brick.

Though the Carboniferous Limestone that surrounds the coal basin appears to be considerably dolomitic, especially on the eastern side, no dolomite for the basic steel process is produced. In one locality the limestone has been proved by analyses to be too siliceous for this purpose. Other quarries have been sampled with a view to ascertaining whether the same siliceous character prevails elsewhere.

SOUTH WALES AND MONMOUTHSHIRE.

In this district silica-bricks are the chief refractory product, firebricks being less important.

The silica-bricks are made from the quartzites of the Millstone Grit, the stone being raised at or near Dowlais, Hirwaun, the Vale of Neath, the Vale of Tawe, the Black Mountain (near Brynamman), Llandybie (near Llandilo), Kidwelly, and Tempeton (near Narberth). The same formation yields also materials for ground ganister and hearth-sands for steel-furnaces. There are inexhaustible reserves.

The fireclays occur in the Lower Coal Series and Pennant Series of the Coal Measures. They are manufactured into ordinary firebricks, blast-furnace blocks, blocks for steel- and zinc-furnaces, cupola-linings, boiler-seatings, coke-oven bricks, hot-blast stove-bricks, flue-covers, ladle-bricks, sleeves, stoppers and nozzles, tuyeres, &c., &c. Ground fireclay is supplied for ladle-linings and for use in copper-, zinc-, and tin-works.

Though much of the Carboniferous Limestone on the eastern and south-eastern margins of the coalfield is dolomitic, none of it is yet worked for use in the steel-furnace hearths or converters. It remains to be proved whether it is sufficiently rich in magnesia and free from silica. A local development of dolomite at Clydach, near Abergavenny, promises to be suitable for this purpose, though the reserves are limited.

There are no important deposits of moulding-sand in South Wales, but suitable material is manufactured from the disintegrated quartzites and sandstones of the Millstone Grit, or imported from the Bunter districts of Staffordshire and Worcestershire.

Hearth-sands are obtained from the disintegrated quartzites and sandstones of the Millstone Grit, and in one case from quartzites in the Old Red Sandstone.

CORNWALL AND DEVON.

Firebricks are made from disintegrated granite.

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(3) Scotland.

The general results of the investigations in Scotland may be stated briefly as follows:—

Hearth Sands.—The holding up of the supply of natural Belgian sand, used almost universally before the war for open-hearth acid steel-furnaces and linings of converters in the Bessemer process, has created a large demand for sand suitable for this purpose. This has been met by the importation of a limited amount of Dutch sand, and by the use of ground sandstone from different localities in the South of Scotland. These sandstones, which are chiefly of Millstone Grit and Carboniferous Limestone age, have a high silica-content, but apart from their chemical composition produce, when ground, a sand inferior in physical characters to the round, even-grained, natural Belgian product.

It is indeed believed by the users that no Scottish sand, hitherto produced, can compete, either in quality or price, with the Belgian sand as obtained under pre-war conditions; it is thus probable that these sandstones may have only a temporary value as a source of hearth-sand.

Ganister and other material for Silica Bricks.—There is a constant and increasing demand for bricks equal in quality to the best Sheffield and Welsh silica-bricks for use in steel and other high-temperature furnaces; those at present made from Scottish ganisters being for the most part not sufficiently resistant to be used in the vital parts of such furnaces.

Silica-bricks were at one time manufactured by the Eglinton Silica Brick Co., Ltd., Glasgow, from chalk-flints brought from Antrim, the Thames, and the northern coast of France. The material for silica-bricks now being made in Scotland is chiefly derived from the 'ganisters' or siliceous sandstones associated with the Upper and Lower Fireclays of the Millstone Grit of Lanarkshire and Stirlingshire, and also, to a small extent, from sandstone of Carboniferous Limestone age. A ganister lying near the base of the limestone series along the borders of Edinburghshire and Peeblesshire has lately been analysed and tested and seems likely to yield refractory material of high quality, the silica-content of some of the samples being up to 98·8 and 99·4 per cent. This ganister is about to be opened up between Carlops and Macbiehill, Peeblesshire.

Certain highly siliceous quartzites on the coasts of Islay and Jura; on the north shore of Loch Leven, east of Ballachulish; and in the neighbourhood of Dalmally, Argyllshire, have been examined by the Survey and are suggested as potential sources of material for silica-bricks. Specimens from different localities in these areas have been submitted for analysis and testing.

Samples of some of these quartzites have been tested by the Eglinton Silica Brick Co., Glasgow, and the rock from Loch Leven is regarded by them as the best suited for the manufacture of silica-bricks.

The amount of rock available at the localities mentioned is large. It lies at or close to the surface and, in the case of the first two areas, conveniently for transport by sea.

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The radiolarian cherts of Lower Silurian age at Abington in the Clyde Valley and on the Ayrshire coast near Ballantrae have been sampled for analysis with a view to their suitability for refractory material, and to these potentialities may be added a number of siliceous sandstones in the neighbourhood of Edinburgh, in Lanarkshire, Ayrshire, and the Sanquhar Coalfield, Dumfriesshire.

Fireclay.—The fireclays in the Millstone Grit of Lanarkshire and Stirlingshire have long been known as a source of material for high-class refractory products. These include bricks and blocks for use in the crowns and linings of steel-, glass-, and chemical furnaces; for coke-ovens, gas-retorts, kilns, oil-furnaces (locomotive and marine); nozzles and stoppers and other fireclay-goods.

The clays are derived from two horizons in the Millstone Grit —the Lower Fireclay near the base, and the Upper Fireclay in the upper part of the series.

There are ample reserves of material in sight to meet all present demands, while large fields, especially of the Lower Fireclay, are as yet almost untouched.

Clays of secondary quality at the base of the Coal Measures near Falkirk; in the Calciferous Sandstone of Renfrewshire, and beneath the coal-seams in several localities in the Central Valley, Ayrshire and Fife are also used in the production of ordinary fireclay-goods. The fireclays of North Ayrshire have been the subject of recent investigation by the Survey and seem likely to yield material of high refractory value. The Ayrshire clays also occur at two horizons—above and below the Millstone Grit lavas. The Lower Fireclay is mined at Monkcastle, Dalry, and provides bricks and blocks for local use in steel-, iron- and zinc-furnaces; the more varied shapes are sent to London for special purposes.

The Upper Fireclay of Ayrshire, which has been traced from the shore at South Bay, Saltcoats, eastwards towards Kilmarnock, is peculiar in being very hard and well jointed, and having a conchoidal fracture. It also contains an unusual proportion of alumina, sometimes as high as 47·5 per cent. Oxide of titanium, usually in the form of rutile, is also abundant. This clay has been analysed and tested, but is not yet worked. It is worthy of consideration as a clay with a high percentage of alumina.

Dolomite.—The dolomite at present used in basic steel processes in Scotland is chiefly derived from the Magnesian Limestone of the North of England. Considerable areas of dolomite of Cambrian age are found in West Sutherland, West Ross, and near Broadford in Skye, but the quality of the stone does not appear to be high enough to meet the cost of carriage from these remote regions.

A dolomite-band of the Appin Limestone, one of the members of the Lochaber Series of metamorphic rocks, has recently been opened up at Duror, in Appin, North Argyllshire. Hand-samples of the rock have been analysed and reported on as likely to give quite a good dolomite after burning. A large demand and output would, however, be necessary to cover the cost of

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production and carriage, and to allow the material to be put on the market at a price approaching that of North of England dolomite.

Magnesite-bricks are now being made on a large scale to meet present demands by the Eglinton Silica Brick Co., Glasgow, but entirely from imported material.

The Dalry Ironstone Field, Ayrshire.

Following upon an increasing demand for iron-ore in Scotland, the late Dr. Clough, after examining the plans of old hæmatite-mines, decided that, under existing conditions, the Dalry field in Ayrshire was one of the most promising sources of ironstone. Mr. Dinham and Mr. Wilson, acting under Dr. Clough, as District Geologist, were accordingly detailed to make a revision of the six-inch sheets of that district. Mr. Dinham examined the ground north of a line passing east and west through Glengarnock, while Mr. Wilson revised the maps to the south of this line.

In the area revised by Mr. Dinham, a considerable advance in detail was made on the original survey, and the following average sequence was established with the aid of the various natural sections and bore-journals, and of the exposure in the cutting of the North Johnstone Loop Line of the Glasgow and South Western Railway.

	Thickness.			Depth below Index.		
	Fms.	ft.	in.	Fms.	ft.	in.
Index Limestone	0	4	10	0	0	0
Strata mostly fireclay and fakes	6	3	0	6	3	0
Dirty Coal 4 in. to 12 in....	0	0	8	6	3	8
Sandstone and fireclay	0	4	0	7	1	8
Kilbirnie Wee Coal	0	2	3	7	3	11
Sandstone and fakes	3	3	0	11	0	11
Blaes, with *Lingula* near base	3	0	0	14	0	11
Kilbirnie Smithy Coal 3 ft. to 3 ft. 6 in. ...	0	3	3	14	4	2
Fireclay and sandstone	1	4	0	16	2	2
Kilbirnie Main Coal 4 ft. to 5 ft.	0	4	6	17	0	8
Sandstone and fakes	3	0	0	20	0	8
Kilbirnie Stone or Stoney Coal 2 ft. 11 in. to 3 ft. 3 in....	0	3	1	20	3	9
Sandstone and fakes	1	4	0	22	1	9
Coal or Coaly Blaes 1 ft. 3 in. to 1 ft. 6 in. ...	0	1	4	22	3	1
Strata, about	7	0	0	29	3	1
Borestone Coal	0	4	2	30	1	3
Strata	2	1	0	32	2	3
Coal 1 ft. to 1 ft. 6 in.	0	1	3	32	3	6
Sandstone and fireclay	1	2	0	33	5	6
Blaes with thin ironstone ribs	3	0	0	36	5	6
Sandstone 1 ft. to 2 ft.	0	1	6	37	1	0
Weir Coal 6 in. to 11 in.	0	0	9	37	1	9
Sandstone and fakes	2	1	0	39	2	9
Irony parrot with *Lingula*	0	0	4	39	3	1
Sandstone and fakes	2	1	0	42	4	1
Faky blaes and blaes with ironstone ribs	3	0	0	44	4	1
Fakes and sandstone	2	3	0	47	1	1
Newfaulds Coal	0	0	11	47	2	0
Strata, mostly fakes and sandstone ...	8	3	0	55	5	0
Faky blaes	4	0	0	59	5	0

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	Thickness.			Depth below Index.		
	Fms.	ft.	in.	Fms.	ft.	in.
Blaes with ribs (Logan's Bands) of ironstone and limestone (5–12 in.), containing *Lingula*, entomostraca, and fish-remains	5	0	0	64	5	0
Sandstone and fakes with thin coal ...	5	0	0	69	5	0
Blaes with thin ironstone-ribs, barren ...	3	1	0	73	0	0
Dalry Blackband Ironstone position (coal and ironstone)	0	1	1	73	1	1
Fireclay and blaes with balls	1	3	6	74	4	7
Coal	0	0	4	74	4	11
Sandstone	0	5	6	75	4	5
Maich Mussel Band Ironstone, limy, 1 ft. 3 in., in blaes with ironstone-ribs, one 10 in. (kingley)	3	0	0	78	4	5
Sandstone	4	3	0	83	1	5
Blaes	0	4	0	83	5	5
Kirnhole Coal, 4 in.—6 in.	0	0	5	83	5	10
Sandstone and fakes	5	0	0	88	5	10
Blaes	2	0	0	90	5	10
Blaes full of *Lingula* with Pundeavon Ironstone (7–12 in.) in middle	2	0	0	92	5	10
Blaes	2	0	0	94	5	10
Johnstone Shell-Bed (blaes with marine fossils) about	1	0	0	95	5	10
Blue *limy kingles* or impure Clayband Ironstone, about	0	2	0	96	1	10
Blaes	0	4	0	96	5	10
Clayband-ironstone rib	0	0	3	97	0	1
Blaes, 2 fms. in south; towards north fakes and sandstone come in here and increase the thickness to about 8 fms., average...	5	0	0	102	0	1
Dalry Main Clayband Ironstone, 13–20 ins. ...	0	1	5	102	1	6
Grey blaes with entomostraca, 3–12 ins. ...	0	0	8	102	2	2
Blaes mostly barren	3	0	0	105	2	2
Blaes with *Lingula*, and at base *Posidonomya corrugata*	4	3	0	109	5	2
Top Hosie Limestone and marine fossils (Limestone D), up to	0	0	10	110	0	0
Blaes with a slaty rib full of *Posidonomya corrugata*	0	3	0	110	3	0
Lillie's Limestone (Limestone C), 1 ft. 7 in. to 2 ft.	0	1	9	110	4	9

The Index Limestone is seen only in the railway-cutting. The main basin of the Kilbirnie Coals lies in the neighbourhood of Glengarnock, and has been mostly wrought out. A small basin was also wrought long ago in the neighbourhood of Kerse Farm, but the revision shows that an upthrow fault of about 50 fathoms runs east and west through the first bridge north of the viaduct over the Maich Water, so that the Kilbirnie Coals are thrown off to the north of this fault, unless some of them occur near the surface in a small area a little south-east of Newfaulds steading. This area is believed to lie in the deepest part of the basin, but its extent depends on the unknown prolongation of the big upthrow which runs south-west through Lochside station.

Logan's bands take their name from the proprietor of an old pit where they are said to have been wrought long ago near Baillieston, Kilbirnie. It is believed that the pit was a failure, but from what cause is uncertain. Where exposed elsewhere, as in the Paduff burn just above the Largs road, the seams themselves

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are clayband ironstones of a fair quality. Some of the bands are also seen in the cutting south-west of West Lochridge steading. Other exposures occur in the Millbank Burn, one mile S.W. of Lochwinnoch, but the ironstones here are much more limy.

The Dalry Blackband Ironstone has been wrought at Glengarnock, but was inferior in quality and thickness to the same seam further south. North of Glengarnock it rapidly deteriorates and becomes, so far as is known, quite worthless.

The Maich Musselband Ironstone is a constant horizon in the district, being known at Wheatyfauld, in the Maich Water, and in the railway-cutting on the east side of Lochwinnoch Loch. It is possible that the old pits at the loch-side were opened in this seam.

The Pundeavon Ironstone is seen well in the Pundeavon Burn, 9 inches thick, and is also exposed in the Paduff Burn, and in the Maich Water N.W. of Nervelston, where it is ten to thirteen inches in thickness. It is apt to contain ribs of poor limy ironstone with cone-in-cone structure. The 'Garibaldi' Ironstone, wrought as recently as 1914 at Glengarnock, is believed to be the same seam, but this has not yet been proved to be the case. The section of the 'Garibaldi' Seam in No. 7 Pit was:—

Ironstone ("Tops")	5 inches.
Blaes	12 inches.
Ironstone ("Bottom stone") ...	4 inches.

The Johnstone Shell-Bed is a constant horizon throughout the district, though the marine fauna is not everywhere abundant. It would prove a valuable index to the Dalry Clayband in diamond or shot bores. The peculiar limy kingles which underlie the shell-bed seem to be almost as constant, and have been met with in several chisel-bores to the Clayband.

The Dalry Clayband Ironstone has not been much wrought hitherto in the district except at Glengarnock. It is well exposed in the Gowkhouse Burn near its confluence with the Pitcon Burn, and in the Paduff Burn, averaging 14 to 15 inches thick. It is not again exposed further north except in the Lora Burn, 350 yds. S.E. of Glenlora Bridge, where it is not less than 13 inches. Old bores on Gavelmoss, where it appears to have been wrought on a small scale, record a thickness of 14 to 21 inches, the seam being in two plies separated by a few inches of blaes. This ironstone could be proved by a shallow bore in the Pundeavon Burn (where it should be about 12 fathoms below the Pundeavon Ironstone) 100 yds. S. of the Kilbirnie Filter Beds; and in the Maich Water, where a bore in the corner of the L-shaped bend, 300 yds. S.W. of High Langstilly should find the Clayband at less than 10 fathoms depth. The thickness of this seam in No. 7 Pit at Glengarnock averaged 18 inches. In No. 6 Pit it was 16½ inches and divided by blaes-partings into three ribs.

Mr. Wilson reports that in the district revised by him there are three ironstones which may be considered as of economic

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importance, namely, the Dalry Clayband, the Dalry Blackband, and the Ironstones associated with the lavas of the Millstone Grit Series.

Dalry Clayband Ironstone.—To the North of the large boundary-fault which runs from Ardrossan in a north-east direction past Monkcastle and along the course of the Dusk Water the Clayband Ironstone may usually be considered as workable. It varies in thickness from 11 to 16 inches. To the south of this fault, the thickness is much less, being only 5 or 6 in. near Monkredding. The present workings on the Blair Estate south of Dalry show that this thinning occurs as the fault is approached from the north.

The Clayband Ironstone has been wrought to a large extent on the south side of the Garnock Water between Dalry and Dockra. A fairly extensive field on the estates of Kersland and Maulside is as yet untouched, and small basins also occur north and south of the Powgree Burn between Manrahead and Coalburn.

At the present time the ironstone is being wrought by W. Baird & Co., at one pit on the Blair Estate, and by Merry and Cunningham, Ltd., at Birsieknow and Dockra.

On the north side of the Garnock Water the Clayband Ironstone has been wrought at a few localities only, notably at Pitcon, Ryesholm, Mossend and Mains. A large untouched field extends from Girthill and Caddell through Burntongues and Swinlees towards Kilbirnie. The *Dalry Blackband Ironstone*, now practically worked out, has been wrought in this area on an extensive scale; these old workings are only about 30 fathoms above the Clayband Ironstone and are now full of water. On this account a considerable amount of pumping and draining would be necessary before the clayband could be worked in many parts of the district. The thickness of the Clayband Ironstone varies from 11 in. near Girthill to 14 or 15 in. near Balgry; an average thickness of 12 in. would give about 10,000,000 tons of unwrought Clayband Ironstone in the district.

Millstone Grit Ironstone.—Highly ferruginous beds have long been known to occur near the top of the Millstone Grit Lava Series in North Ayrshire. In the course of the investigation a number of exposures of these rocks were visited and specimens taken for analysis. The beds vary from 3 ft. to 8 ft. in thickness, and the material is generally a highly decomposed basic lava-flow or flows consisting of a whitish-green or brown base with numerous scattered grains of carbonate of iron (sphaerosiderite). In a few instances the colour is deep-red owing to the carbonate being reduced to the oxide. In some cases the bed is fairly homogeneous throughout, in other cases doggers and strings of good ironstone occur scattered through a ferruginous clayey matrix.

The analyses show that though these beds often contain a fairly high percentage of iron they are rich in silica and alumina, and consequently would be too costly to use as a source of iron under present conditions. It appears that the few occurrences where the ironstone is good, as at the Brackleheugh (Breakplough),

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¼ mile north of Stevenston, must unfortunately be regarded as local enrichments of no great extent.

Messrs. Macgregor and Wilson visited the ironstone bearing rocks of Garron Point, north of Stonehaven. On the south side of the Highland Boundary Fault, an area about 100 yds. wide by ½ mile in length is occupied by a suite of lava-flows and interbedded sediments dipping at an angle of about 40° towards the fault. The ironstone occurs as bands from 1 in. to 6 ft. thick throughout the series, and consists mainly of finely comminuted magnetite and hæmatite in a siliceous matrix. Several specimens were collected for analysis, and the results show that these beds are too rich in silica to be of much value as ordinary iron-ore, while they are too high in phosphorus to be used in the manufacture of ferro-silicon.

Analyses of Dalry Clayband Ironstone, Ayrshire.

1. Gowkhouse Burn, Balgry Farm (top ply).[1]
2. „ „ „ „ (bottom ply).[1]
3. Powgree Burn, ½-mile S.E. of Longbar (16 in. thick).[1]
4. „ „ ¼-mile N.E. of Coalburn (16 in. thick).[1]

—	1.	2.	3.	4.
Iron	29·17	28·81	27·09	24·12
Silica	9·30	10·30	11·50	10·
Alumina	4·67	4·15	4·50	6·43
Phosphorus ...	·56	·55	·698	·656
Sulphur	·073	·087	·192	·189
Lime	7·33	7·56	8·72	12·64
Manganese oxide...	2·14	1·95	1·48	1·58
Magnesia ...	3·90	4·20	3·92	3·24
Loss on ignition ...	29·60	29·20	28·50	29·80

Analyses of Millstone Grit Ironstone, Ayrshire.

1. Brackleheugh (Breakplough), ¼-mile north of Stevenston (from a 4-ft. seam).[1]
2. Glen Burn, ¼-mile north-west of Corsinkell and 1¼-miles north of Stevenston. Top seam 12 in. to 18 in. thick.[1]
3. Same locality. Bottom seam (6–7 ft. thick).[1]
4. Same locality. Thin veins in Bottom seam.[1]

—	1.[2]	2.	3.	4.
Iron	42·43	28·20	17·16	33·10
Silica	15·	10·60	18·70	10·50
Alumina	9·80	14·70	27·70	9·
Phosphorus ...	·061	·022	1·89	·044
Sulphur	·020	·275	·110	·046
Lime	·70	2·48	2·03	1·48
Manganese oxide...	·465	·28	·18	1·20
Magnesia	·28	3·42	2·45	2·77
Loss on ignition ...	11·50	26·80	23·40	27·80

[1] By favour of Messrs. D. Colville & Sons, Glengarnock.
[2] See also p. 24.

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Analyses of Ironstone from Garron Point.

Specimen No.	2.[1]	3.[1]	6.[1]	7.[1]
Iron	35·56	43·96	40·32	33·04
Silica	34·30	24·40	31·80	42·40
Alumina	4·70	2·60	0·90	3·10
Phosphorus ...	0·68	1·32	0·766	0·541
Sulphur	0·120	0·137	traces	0·041
Carb. of lime ...	1·80	4·82	2·68	4·70
Manganese ...	0·48	0·64	0·24	0·32
Insoluble	39·00	27·00	32·70	45·50

An old quarry in the Ochil Hills about ¾ mile from Menstry Station and 600 ft. above the level of the valley was noted by Mr. Wilson to be in a vein of calcite about 11 ft. thick. Samples taken for analysis gave the following result.

Analysis of Calcite, Menstry, Ochil Hills.

	Per cent.
Silica	·40
Oxide of iron	·36
Alumina	·34
Lime	55·
Magnesia	·60
Sulphur	trace
Phosphorus	trace
Loss on ignition	43·30
Water	·48

The above analysis shows that the rock is an exceptionally pure limestone. Practical tests made on samples have proved that it makes an excellent bind in the manufacture of silica-bricks, but the fact that it falls to powder on calcining condemns it as a flux for blast-furnaces.

III.—PETROGRAPHICAL WORK.

England and Wales.

Petrographical work during the past year has been devoted more particularly to reporting upon the distribution of useful rocks and minerals, investigating the character of refractory materials used in the steel-trade, and reporting to other Government Departments and to the general public on a variety of scientific and economic inquiries which have arisen in connection with the War.

[1] By favour of Messrs. William Dixon, Ltd., Calder Iron Works, Coatbridge.

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In addition, Dr. Thomas has reported on rocks from North Wales and the Midlands collected by the officers of the Survey, and from the Gold Coast and Easter Island collected by private individuals.

Scotland.

The Scottish petrographical work, carried on by Dr. Thomas in the London Office, has been mainly in connection with the survey of the Ayrshire Coalfield, the study of Scottish refractory materials and the description of rocks obtained from a variety of bore-holes.

The descriptive petrology of Sheet 54 (Moor of Rannoch) has been completed.

IV.—CHEMICAL WORK.

The work of the Chemical Department has lain chiefly in the analyses made in preparation for a 'Special Report' on British Refractory Materials. Seventeen analyses of ganisters and silica-rocks, and four of fireclays have been completed during the past year. In addition four complete, and five partial analyses were made of rocks which appeared likely to prove to be of economic value.

1-ft. layer of sphaerosiderite concretions in fireclay in Coal Measure Series. No. 2 bore, Byreburn, Canonbie. 1-in. sheet 11, 6-in. sheet. Dumfries 53, SE.$^{E.}$ At depth of 13 yds., 2 ft., 6 in. About 550 ft. NE. of Byreburnfast Bridge. Slice No. 19466. Lab. No. 470.

Musselband, a fine-grained carbonaceous shale occurring below the wee coal (Coal Measure Series), about 20 in. thick, in old quarry about ¼-mile W. by S. of Church in N. part of Stevenston. 1-in. sheet 22. 6-in. sheet. Ayr 16 NW.$^{E.}$ Slice No. 19511. Lab. No. 472.

Musselband, a carbonaceous ironstone (sphaerosiderite) containing organic remains. A large portion of the rock consists of iron carbonate, showing well-developed spherulitic structure. Kilmarnock Water, 400 ft. SE. of Dean Castle. 1-in. sheet 22, 6-in. sheet. Ayr 18 SW.$^{E.}$ Slice No. 19512. Lab. No. 473.

Slice No. ...	19466.	19511.	19512.
Lab. No. ...	470.	472.	473.
Fe_2O_3	58·78	12·80	8·30
CaO	·98	—	—
MgO	·83	—	—
P_2O_5	·58	—	—
S	·12	—	—
C	—	2·73	—

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Whitish grey clay. A large mass cropping at surface. Treven Farm. 1-in. sheet 337. 6-in. sheet. Cornwall 19 NW. Museum No. C. 3245. Lab. No. 454.

Laminated Glacial clay from West Wales. Lab. No. 474.

—	(Museum No. C. 3245.)	—
Lab. No.	454.	474.
SiO_2	61·08	58·30
TiO_2	1·54	1·15
Al_2O_3	25·21	20·49
Fe_2O_3	·65	8·07
FeO	·20	—
MnO	·07	·12
CaO	·03	·09
MgO	·62	1·74
K_2O	5·21	3·61
Na_2O	·24	·81
Li_2O	nt. fd.	nt. fd.
H_2O at 105° C.	·38	·96
H_2O above „	4·43	4·28
P_2O_5	·12	·28
FeS_2	·08	·14
CO_2	·16	·24
Total	100·02	100·28

The top 3½ ft. of the ochre-bed which is believed to represent the Gilmerton Limestone (Carboniferous Limestone Series). South side of burn, 2,600 ft. NW. of Dryden. 1-in. sheet 32, 6-in. sheet. Edin. 7 SE.[E]. It was used formerly as a paint or wash. Lab. No. 475. ANAL. E. G. RADLEY.

The top part of an ochre-bed which represents the top part of the North Greens Limestone (Carboniferous Limestone Series). South side of burn, 2,100 ft. NW. of Dryden. 1-in. sheet 32, 6-in. sheet. Edin. 7 SE.[E]. A somewhat similar bed was formerly used as a paint. Lab. No. 476.
ANAL. E. G. RADLEY.

—	Lab. No. 475.	Lab. No. 476.
SiO_2	82·75	69·76
Fe calculated as Fe_2O_3 ...	5·69	14·18
FeS_2	nt. fd.	nt. fd.
P_2O_5	·19	·27

On treating the rocks with hydrochloric acid, the following results were obtained:—

Insoluble residue	89·47	78·34
Fe calculated as Fe_2O_3 ...	5·37	14·13

The specimens were dried at 105° C. before the estimations were made, because as sent in for analysis, Lab. No. 475 contained over 19% of H_2O and Lab. No. 476, over 25% H_2O.

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Ironstone bed 4 ft. thick. Rotten lava or parting between lavas in Millstone Grit Series. ½-mile north of Stevenston. Ayrshire. 1 in. sheet 22. Lab. No. 488. ANAL. E. G. RADLEY.

Lab. No. ...	488.
Insoluble residue	26·09
SiO_2	·78
TiO_2	·83
Al_2O_3	5·86
Fe_2O_3	46·86
FeO	5·65
MnO	·50
(CoNi)O	·03
CaO	·39
MgO	·57
K_2O	·08
Na_2O	·49
Li_2O	trace
H_2O at 105° C.	1·50
H_2O above „	6·63
P_2O_5	·47
FeS_2	·03
C	—
CO_2	3·29
SO_3	—
Total ...	100·05

All iron calculated as Fe	...	...	37·21
FeS_2	„	„ S	...	...	·02
P_2O_5	„	„ P	...	...	·20

V.—PALÆONTOLOGICAL WORK.

ENGLAND AND WALES.

Work has been continued on the deep borings and sinkings in Kent. Dr. Kitchin and Mr. Pringle have examined extensive suites of specimens from the additional material collected by the latter. Mr. Pringle's summarised report on three of the borings is published in Appendix II., p. 34.

Mr. Allen has revised the nomenclature of a large series of Carboniferous fishes in the Museum. He has also rearranged and catalogued the Cretaceous lamellibranchs and gasteropods, the Mollusca from the Norwich Crag and Weybourn Crag, and the plants and molluscs from the Forest Bed.

A row of teeth of the rare fish *Edestus*, from shale in the Millstone Grit, near Huddersfield, has been presented to the Museum by Mr. E. Crowther. This exceptionally fine specimen is being described by Dr. A. Smith Woodward, F.R.S.[1]

[1] See also *Abstr. Proc. Geol. Soc.*, No. 994, Oct. 4th, 1916.

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The following specimens in the Museum have been figured and described:

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1915. (Published 1916.)

The Fossil Fishes of the English Wealden and Purbeck Formations.

By DR. A. SMITH WOODWARD, F.R.S.

Hybodus basanus *Egerton*, pl. i, f. 1, p. 6.
„ ensis *A. S. Woodw.*, pl. ii, figs. 2-5, p. 11.
Coccolepis andrewsi *A. S. Woodw.*, pl. iv, f. 2, p. 24.
Lepidotus minor *Ag.*, pl. v, f. 8, p. 29; pl. vi, f. 1, p. 28.

A Monograph of the British Asterozoa.

By MR. W. K. SPENCER, M.A.

Caractacaster caractaci (*Gregory*), pl. ii, f. 4, p. 80; pl. iii, f. 1, p. 82.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, Vol. LXXI, Part 2.

By DR. STANLEY SMITH, B.A.

Lonsdaleia duplicata duplicata (*Martin*), pl. xvii, f. 2, p. 238.
„ floriformis (*Martin*), pl. xix, f. 8, p. 250.

SCOTLAND.

The fossils added to the collection during the year have been obtained chiefly from borings in the Carboniferous areas of the Central Valley, South Scotland and Ayrshire. The strata traversed range from Coal Measures to Calciferous Sandstone, and the specimens obtained have proved useful to Dr. Lee in determining horizons. Thus in the case of a boring in the Coal Measures of the Kilmarnock district the occurrence of certain 'mussel-bands' served to corroborate other evidence as regards the horizon reached. The evidence of fossils also helped in the reading of a complicated sequence in a boring in the Canonbie district, where the presence of a fault was suspected, but could not be established on lithological grounds. In the case of other borings carried through the Carboniferous Limestone in search of the Limestone Coals, the fossils substantiated the index value of certain assemblages, as for instance in a further record of *Edmondia punctatella* in its usual position below the Calmy Limestone, and in the identification of a core of the Index Limestone by the abundance of *Productus latissimus* it contained.

VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Museum was closed to the public, except for special enquiries, from March 6th. This provided an opportunity to redistribute many of the larger exhibits in the Hall with a view to increasing the available space as much as possible.

On March 14th a marble bust of Sir Archibald Geikie, O.M., F.R.S., for the preparation of which funds had been provided

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by former colleagues, old pupils, and numerous friends, was presented to the Board of Education on behalf of the subscribers by Sir William E. Garforth, and accepted by the Right Hon. J. Herbert Lewis, on behalf of the Board. On the same occasion a marble replica of the bust was presented to Sir Archibald Geikie on behalf of the subscribers by the Right Hon. Lord Rayleigh, O.M., F.R.S. The original, which was executed by Prof. E. Lantéri, has been placed in the Museum of Practical Geology.

The greater part of the year has been occupied in dealing with the materials collected during the field-investigation of the British resources of refractory rocks, sands, ganisters and fireclays. More than 2,000 samples have been collected, and these have been registered, card-catalogued and prepared for the purposes of Museum exhibition.

List of Donations during the year 1916.

Acton, A., Esq.—Two micro-slides, Bwlchgwyn Quartzite (Millstone Grit), near Wrexham.

Ashcroft, F. N., Esq.—Minerals on joint-faces, from Penmaenmawr, North Wales. (Three specimens.)

Bailey, Sec.-Lieut. E. B., R.G.A.—Thirteen rock-specimens from Drake's Island, Plymouth Sound.

Barclay, Lieut., The Executors of the late.—Six *Micrasters* and two *Conulus* from the Upper Chalk of Kent and Surrey.

Barrow, G., Esq., F.G.S.—Three micro-slides of rocks, from Anglesey.

Brown, G. F., Esq.—A specimen of *Ventriculites radiatus* Mant. from the Upper Chalk of Haling Pit, near South Croydon.

Buckman, S. S., Esq., F.G.S.—An ammonite from the Lower Fuller's Earth of the Dorset Coast.

Butterworth, F. M., Esq.—Fragment of coal with impression of *Lepidophloios laricinus* (Sternb.).

Carus-Wilson, C., Esq., F.R.S.E.—A Silurian gasteropod from Shucknall, Herefordshire.

Colonies, The Under-Secretary of State for the.—Two micro-sections of kerosene shale with *Reinschia australis*, one from New South Wales, the other from West Falkland.

Crowther, E., Esq.—A row of teeth of *Edestus* from Millstone Grit shales at Brockholes, near Huddersfield, Yorkshire.

Draper, D., Esq., M.I.M.M.—Diamond, small crystal, from Agua Suja Mine, Bagagena Minas, Brazil.

Faber, H., Esq.—Diatomaceous clays from Denmark.

Farnley Iron Works Co., Ltd., Messrs. the.—Refractory materials.

Gallewski, B., Esq.—Zircon, also two samples of Graphite from Madagascar.

Greenly, E.—Thirty rock-specimens and sections from Anglesey.

Hamling, J. G., Esq., F.G.S.—A series of Devonian and Culm fossils from North Devon.

Heron-Allen, E., Esq., F.L.S., F.R.M.S.—A specimen of Alveolina (Mixen) Rock, in the soft state, from Selsey Bill, Sussex.

Howe, J. Allen, Esq., B.Sc.—A specimen of *Alveolites septosus* (Flem.) from the Carboniferous Limestone of Monsal Dale, Derbyshire.

Johnston, Miss Mary.—Portion of a brick made from "Ås" sand, Kallbohn, Sweden.

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KING, CAPTAIN W. B. R., B.A.—A series of fossils and rock specimens from Chloritic Marl, Chalk and Tertiary Beds of Northern France. A series of specimens, mainly rocks, from the Western Front (North France).

LAMPLUGH, G. W., ESQ., F.R.S.—A series of fossils from the Greensand of Shenley Hill, near Leighton Buzzard, and other Cretaceous specimens from Faringdon, etc.

LANGSLOWLOCK, E. A., ESQ.—Topaz from Tin washings, Nigeria.

LAWRENCE, L. A., ESQ.—A small cut purple diamond.

MARR, DR. J. E., F.R.S.—Two specimens of metalliferous vein, metamorphosed by Shap granite.

MOULDEN, J. C., ESQ., M.I.M.M.—Two specimens of zinc retort containing zinc spinel.

NORMAN, LADY.—Fourteen rocks collected in Discovery Bay during Capt. Scott's Expedition, 1910-1913, by Lieut.-Commander H. E. de P. Rennick, R.N.

POCOCK, LIEUT. R. W., R.G.A.—Ten igneous rocks from the Isle of Imbros.

REYNOLDS, PROF. S. H., SC.D.—Twenty-one specimens of igneous rocks, from Monmouthshire and Somerset.

ROBINSON & SON, MESSRS. J.—Samples of Blende from the Ladywash Mine, Eyam; Lump Fluor, Twelve Meres Mine, Eyam; Lump Barytes, Cupola Mine.

RUSSELL, F., ESQ. (THE GENERAL REFRACTORIES CO., LTD.).—Refractory materials.

SHERLOCK, DR. R. L.—A specimen of *Acentrophorus varians* (Kirkby) from the Magnesian Limestone of Fulwell, North-West of Sunderland.

SIDDONS, E. H., ESQ.—One specimen of Quartz-orthoclase porphyry from Axim beach, Pepreh Point, Gold Coast, West Africa.

SIMPSON, J. R., ESQ.—Six marine fossils from the Millstone Grit shales at Brockholes, near Huddersfield.

SMITH, H. G., ESQ.—Slide and specimen of Sapphire-bearing Lamprophyre, Lurgecombe Mill, Ashburton.

SMITH, JOHN, ESQ.—A micro-slide of Amber in Carboniferous Coal.

SNEYD COLLIERIES CO., LTD., MESSRS. THE.—Refractory materials.

TEALL, SIR J. J. H., F.R.S., ETC.—A specimen of Quartzite with supposed *Lingula*, from the Bunter Pebble Bed, near Birmingham.

TYRRELL, G. W., F.G.S.—Two micro-slides of Lugarite and Lamprophyre segregation, Old Quarry, Barshaw, near Paisley.

WADE, DR. A.—A series of Ordovician fossils from the Welshpool district, described in the *Quart. Journ. Geol Soc.*, vol. lxvii, p. 415.

WHITEHEAD, CAPT. T. H., F.G.S.—Two specimens of igneous rock from the Isles of Imbros and Lemnos.

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

SIX-INCH REFERENCE MAPS.

The following 67 standard copies of six-inch quarter-sheets have been made from the field-copies, and are available for reference:—

Bedfordshire, 32 S.W., 32 S.E. (Herts. 18 S.E.); 33 S.W. (Herts. 19 S.W.); 34 N.W. (Herts. 26 N.W.), 34 N.E. (Herts. 26 N.E.), 34 S.W. (Herts. 26 S.W.), 34 S.E. (Herts. 26 S.E.).

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Hertfordshire, 25 N.W., N.E., S.W., S.E.; 27 N.W. (Beds. 35 N.W.), 27 S.W.; 32 N.W., N.E., S.E.; 33 N.W., N.E., S.W., S.E.; 34 N.W., S.W.; 38 N.W., N.E.; 39 N.W.

Leicestershire, 42 N.E.; 43 N.W., N.E.; 43 S.W. (Warw. 12 S.W.), 43 S.E.; 48 N.E.

Warwickshire, 9 N.E., S.E.; 10 N.W., 10 N.E. (Leic. 41 N.E.), 10 S.W., S.E.; 11 N.W. (Leic. 42 N.W.), 11 S.W. (Leic. 42 S.W.), 11 S.E. (Leic. 42 S.E.); 15 N.E., S.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W., N.E., S.W., S.E.; 18 N.W. (Leic. 48 N.W.), 18 S.W. (Leic. 48 S.W.), 18 S.E. (Leic. 48 S.E.); 20 N.E., S.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., N.E., S.W., S.E.; 23 N.W., 23 N.E. (Leic. 52 N.E.), 23 S.W., 23 S.E. (Leic. 52 S.E.; Northants. 21 S.E.).

II.—MEMOIRS.

Published Memoirs.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1915, pp. 55, text figures 3. Price 1*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. I.—Tungsten and Manganese Ores. Second Edition. By H. Dewey and C. E. N. Bromehead, B.A.; with contributions by T. Eastwood, A.R.C.S.; G. V. Wilson, B.Sc.; and R. W. Pocock, B.Sc., pp. 59, text figures 2. Price 1*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. II.—Barytes and Witherite. Second Edition. By R. G. Carruthers; T. Eastwood, A.R.C.S.; G. V. Wilson, B.Sc.; R. W. Pocock, B.Sc.; and D. A. Wray, B.Sc.; with contributions by H. Dewey and C. E. N. Bromehead, B.A., pp. 93, text figures 6. Price 2*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. IV.—Fluorspar. By R. G. Carruthers; R. W. Pocock, B.Sc.; and D. A. Wray, B.Sc.; with contributions by H. Dewey and C. E. N. Bromehead, B.A., pp. 38, text figures 2. Price 9*d*.

Special Reports on the Mineral Resources of Great Britain. Vol. V.—Potash-Felspar, Phosphate of Lime, Alum Shales, Plumbago or Graphite, Molybdenite, Chromite, Talc and Steatite (Soapstone, Soap-Rock and Potstone), Diatomite. By A. Strahan, Sc.D., LL.D., F.R.S.; J. S. Flett, D.Sc., LL.D., F.R.S.; and C. H. Dinham, B.A.; with contributions by C. T. Clough, M.A.; T. Eastwood, A.R.C.S.; and A. F. Hallimond, B.A., pp. 41, text figures 3. Price 1*s*.

On the Thicknesses of Strata in the Counties of England and Wales exclusive of rocks older than the Permian. By A. Strahan, Sc.D., LL.D., F.R.S.; T. V. Holmes; H. Dewey; C. H. Cunnington, B.Sc.; W. C. Simmons, B.Sc.; W. B. R. King, B.A.; and D. A. Wray, B.Sc., pp. 172, text figures 36. Price 4*s*. 6*d*.

The Geology of the South Wales Coalfield. Part XII.—The Country around Milford (Explanation of Sheet 227). By T. C. Cantrill, B.Sc.; E. E. L. Dixon, B.Sc.; H. H. Thomas, M.A., Sc.D.; O. T. Jones, M.A., D.Sc., pp. 185, plates 7, text figures 30. Price 2*s*. 6*d*.

SCOTLAND.

I.—MAPS.

Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the Office for reference:—

Argyll, 70 N.W., N.E.; 124; 149.

Elgin, 15.

Inverness, 26 N.W., N.E.; 56 N.E., S.E.; 72 N.E., S.W., S.E.; 86 N.E., S.E.; 101 N.E., S.E.; 102.

Nairn, 4; 7; 8.

Ross, 23, 27, 49, 53, 60, 74, 86, 98, 99, 118 N.W., N.E., S.W.; 119 N.E.; 120 N.W., N.E.

Sutherland, 41 N.W.; 51; 61.

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II.—MEMOIRS.

Published Memoirs.

Summary of Progress for 1915. See p. 28.

The Economic Geology of the Central Coalfield of Scotland. Description of Area V. (Glasgow East, Chryston, Glenboig and Airdrie). By C. T. Clough, M.A.; L. W. Hinxman, B.A., F.R.S.E.; W. B. Wright, B.A.; E. M. Anderson, M.A., B.Sc.; R. G. Carruthers; with contributions from R. Kidston, LL.D., F.R.S.; G. W. Lee, D.Sc., F.R.S.E., pp. 146, plates 13, text figures 5. Price 4*s.* 6*d.*

The Geology of Ben Nevis and Glen Coe and the surrounding Country (Explanation of Sheet 53). By E. B. Bailey, B.A.; and H. B. Maufe, M.A.; with contributions by C. T. Clough, M.A.; J. S. Grant Wilson; G. W. Grabham, M.A.; H. Kynaston, B.A.; W. B. Wright, B.A., pp. 247, plates 12, text figures 33. Price 7*s.* 6*d.*

Special Reports on the Mineral Resources of Great Britain. See p. 28.

APPENDIX I.

On a Deep Boring for Coal at Pollington, Yorkshire.

By W. Gibson, D.Sc.

Recent sinkings and borings around Doncaster have proved an extension of the Middle Coal Measures of the Yorkshire Coalfield eastward under the Permian and Triassic formations, south of an east-and-west line joining Askern (7 miles N.N.W. of Doncaster) and Thorne (12 miles N.E. of Doncaster). North of this line an area to the Ouse, at Selby, has been proved recently by some widely distributed borings, of which this one at Pollington (5 miles N.E. of Askern) is situated 8 miles east of the Visible Coalfield at Pontefract.

The Section (Abstract).

Boring for coal, one half a mile north-east of Heck Station, Yorkshire. Geological Map, Old Series, 87 N.E. 1 inch. New Series Ordnance Map, 79; 6 in. Yorks, 251 N.W. Lat. 53° 41′ 0″, Long. 1° 4′ 50″. Communicated by the North Yorkshire Boring Syndicate.

Height of surface above O.D. about 25 ft.

		Thickness. Ft.	In.	Depth. Ft.	In.
	Top soil	8	–	8	–
Bunter (504 ft.)	Cemented sand (no core)	504	–	512	–
Upper Permian Marl (96 ft.)	Red and blue marl	51	6		
	Anhydrite	16	–	579	6
	Red marl and gypsum	27	–		
	Mottled marl	1	6	608	–
Upper Permian Limestone (90 ft.)	Limestone	10	–		
	Limestone with gypsum and shale	5	–		
	Grey shale	3	6		
	Limestone	7	6		
	Limestone with shale joints	50	–		
	Limestone	8	6		
	Blue shale	1	6		
	Limestone	4	–	698	–
Middle Permian Marl (135½ ft.)	Gypsum	1	–		
	Blue shale and gypsum	5	–		
	Red marl, gypsum and anhydrite	125	–		
	Red anhydrite	4	6	833	6

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		Thickness. Ft.	In.	Depth. Ft.	In.
Lower Permian Limestone (144½ ft.)	Limestone and gypsum	4	–		
	Limestone	140	6	978	–
Permian basal beds (15½ ft.)	Grey shale (*Lingula credneri*) ...	10	6		
	Grey sandstone	5	–	993	6
	Blue fireclay	2	6		
	Grey shale and ironstone bands ...	5	–		
	Grey shale and sandstone	12	–		
	Mottled marl	4	6		
	Grey shale and sandy shale	52	6		
	Grey shale and ironstone bands ...	6	6		
	Dark grey shale	4	6		
	Coal ... ... } [Shafton]	3	2	1,084	2
	Black shale ... } [Shafton]	–	2		
	Coal... ... } [Shafton]	1	–		
	Black shale and fireclay	1	6		
	Coal	1	2	1,088	–
	Fireclay...	3	–		
	Grey shale	12	6		
	Grey shale and sandy shale with two beds of fireclay	26	3		
	Sandy shale	9	–		
	Coal	2	4	1,141	1
	Fireclay	1	–		
	Sandy shale	46	5		
	Coal	1	6		
	Black shale	1	3		
	Shale and fireclay with ironstone nodules	11	3		
	Coal	1	–	1,203	6
	Fireclay...	2	3		
	Grey shale and ironstones	3	–		
	Coal	–	6	1,209	3
	Black shale and ironstone	1	8		
	Coal	–	7	1,211	6
	Fireclay...	1	6		
	Sandy shale	85	–		
	Dark shale	18	–		
	Coal	–	1	1,316	1
	Fireclay and shale	28	11		
	Shaly coal	5	9	1,350	9
	Fireclay...	5	9		
	Black shale with ironstone bands ...	31	–		
	Coal	–	2	1,387	8
	Fireclay, black shale with ironstones	40	10		
	Coal	1	11	1,430	5
	Fireclay, shale and sandstone ...	14	7		
	Shaly coal	–	3		
	Fireclays, shale, and sandy shale ...	148	3		
	Coal	1	–	1,594	6
	Fireclay...	5	6		
	Grey shale and sandy shale [sandstone ? Oak's Rock]	50	–		
	Coal	3	–	1,653	–
	Fireclay...	–	9		
	Shale and sandstone	29	6		
	Black shale	3	–		
	Coal	1	9	1,688	–
	Fireclay and shale	29	3		
	Coal	–	9	1,718	–
	Fireclay...	5	3		

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	Thickness. Ft.	In.	Depth. Ft.	In.
Grey sandstone... } [? Wooley edge	28	9		
Shale with ironstone } or Melton	38	10		
Grey sandstone... } Rock.]	20	5	1,811	3
Shale with ironstone	19	6		
Coal	1	3	1,832	–
Dirt-parting	–	4		
Coal	1	11	1,834	3
Fireclay and shale	4	4		
Coal	–	5	1,839	–
Fireclay...	1	1		
Coal	–	8	1,840	9
Shale and ironstone	2	3		
Sandy shale and shale	40	–		
Coal	1	9	1,884	9
Shale and sandstone	21	9		
Shale and ironstone nodules... ...	15	6		
Coal	4	4	1,926	4
Fireclay and shale with ironstone ...	11	8	1,938	–
Coal	1	2	1,939	2
Dirt	1	–		
Coal	–	10		
Dirt	–	5		
Coal	–	1	1,941	6
Fireclay...	2	–		
Sandstone and sandy shale	16	9		
Shale and ironstone nodules ...	9	3		
Shaly coal	3	9	1,973	3
Fireclay...	2	3		
Shale and sandy shale, ironstone bands...	26	9		
Coal	–	2	2,002	5
Fireclay...	2	3		
Coal	3	–		
Fireclay...	1	2		
Coal	–	2		
Fireclay...	–	4		
Coal	–	2	2,009	6
Fireclay and ironstone balls ...	2	–		
Shale with fireclay and coal 2 in. at 2,026 ft.	15	2	2,026	8
Sandstone and sandy shale	13	1		
Shale	11	5		
Fireclay...	2	10		
Coal parting	–	3	2,054	3
Fireclay...	1	–		
Coal	1	–	2,056	3
Fireclay...	–	6		
Sandstone and shale	38	9		
Grey shale and ironstone bands ...	7	6		
Black shale [*Lingula*]	–	6		
Coal (cannel)	–	6	2,104	–
Black shale	1	6		
Shale with ironstone bands	14	3		
Coal	–	5	2,120	2
Fireclay...	18	4		
Sandy shale and sandstone	107	9		
Shale with ironstone, and sandy shale	78	3		
Coal	–	3	2,324	9
Fireclay...	2	–		
Shale	40	9		
Black shale	5	–		

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal		2	2	2,374	8
Fireclay		3	10		
Coal		–	4	2,378	10
Fireclay		4	2		
Sandstone and shale		19	6		
Coal		–	9	2,403	3
Fireclay		1	–		
Dark shale		2	6		
Coal		1	0	2,407	9
Fireclay		10	6		
Sandy shale and sandstone		37	9		
Black shale		1	–		
Coal		1	6	2,458	6
Fireclay		2	3		
Shale with ironstone bands		33	6		
Blue shale		1	9		
Coal	Warren House Coal.	–	9	2,496	9
Dirt		–	9		
Coal		–	7		
Dirt		–	9		
Coal		–	9		
Dirt		1	1		
Coal		2	–	2,502	8
Black shale and fireclay		2	10		
Coal		2	3	2,507	9
Fireclay		7	9		
Shale with ironstone nodules		29	–		
Coal		–	2	2,544	8
Fireclay		6	4		
Coal		–	3	2,551	3
Fireclay		1	3		
Sandstone and sandy shale		35	6		
Shale		11	–		
Coal	Dunsil.	3	–	2,602	–
Parting		–	6		
Coal		–	3		
Parting		–	5		
Coal		–	8	2,603	10
Fireclay		2	2		
Shale with ironstone nodules		66	6		
Coal		1	8	2,674	2
Black shale		1	–		
Sandstone and sandy shale		114	10		
Dark shale and ironstone		2	–		
Blue shale		3	–		
Coal	Haigh Moor or Glass Houghton Colliery.	–	6	2,795	6
Fireclay parting		3	–		
Coal		2	9	2,801	3
Fireclay		1	6		
Shales, fireclays, and streaks of coal		172	3		
Sandy shale		28	–	3,003	–

End of boring.

The boring was commenced with a diameter of 20 inches. The first 512 ft. through the Bunter Formation did not yield cores; but the Permian and Coal Measures produced good cores, which were 9 in. diameter at 1,593 ft. and 1,920 ft. and 6 in. diameter at 2,496 ft.—that is at those depths at which important coal horizons were entered.

The Permian strata proved to be similar in character to those at Carlton, Barlow and Selby (the Concealed Coalfield of York-

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shire and Nottinghamshire, *Mem. Geol. Surv.*, 1913). The total thickness is 481 ft. as compared with 565 ft. at Carlton, 610 ft. at Barlow, and 624 ft. at Selby, thus showing a steady northerly increment which is in agreement with that prevailing throughout the Concealed Yorks-Notts Coalfield. It is also known, by borings and sinkings, that the general inclination of the Trias and Permian formations is directed nearly due east, and at a rate per mile that brings the base of the Permian deposits to a depth approaching 3,000 ft. from the surface in the region bordering the Trent north of the Askern–Thorne line. Moreover, the rate at which the Permian basement bed slopes eastwards is so nearly uniform that, for this area, contours can be drawn showing its depths from the surface within extremely narrow limits of accuracy. Thus for all practical purposes the thickness and character of the cover to the Coal Measures can be estimated.

No appreciable dip of the Coal Measures could be determined, and since the deflection of the hole was shewn to be slight the thickness of 2,009 ft. proved in the boring may be taken as the true thickness.

The Upper Coal Measures are absent, and the boring ended in Middle Coal Measures about 350 ft. above the Silkstone Coal.

Numerous seams of coal were proved, but with the exception of that of the Warren House the names of the others have been added in square brackets to the section as supplied. There can be little doubt that the seam here taken as the Shafton is the same as the Shafton of Hemsworth Colliery, and the Nostell Seam of Nostell Colliery, and that the group of coals between 1,830–2,104 feet corresponds to that containing the Wathwood, Two-feet, Abdy and Stanley Main Coals of Yorkshire. This group of coals becomes of importance in the northern part of the coalfield, and analyses show that those at 1,834, 1,926, 2,007, 2,602 feet are of good quality.

That the Barnsley seam of the Doncaster region should have been found in the condition of the Warren House is in conformity with what occurs at Askern, and in the Visible Coalfield west of Pollington. The depth to the seam, however, is nearly 200 yds. greater than would have been the case if the low dip observable in the Visible Coalfield had continued eastward to the boring. It may be here remarked that at the Brodsworth Colliery the Barnsley Seam was found at a much shallower depth than was estimated from the dip observable in the nearest coal-workings to the west, nor are these the only cases in which estimated and proved depths have been found to differ in a marked degree. Probably it is safe to allow for a depth ranging between 2,500–3,000 ft. to the Barnsley Coal within the area north of the Askern–Thorne line.

[NOTE.—At the present stage of operations there are reasons against breaking up the cores systematically and investigating the fossil evidence. It may be stated that the characteristic marine band, between 600 and 750 ft. above the Barnsley Coal, and always easily detected in other borings and sinkings was not recognised, though a careful search was made between the depth of 1,700 and 1,950 feet.]

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APPENDIX II.

On Deep Borings for Coal and Ironstone at Bere Farm, Elham and Folkestone, Kent.

By J. Pringle, F.G.S.

The three borings described briefly below were made by the Channel Collieries Trust Ltd., and through the courtesy of Mr. E. O. Forster Brown the Geological Survey was invited to examine the cores, and is now permitted to make known the general results. Specimens were collected by the writer from the various formations passed through during the progress of the boring, and are still under investigation. Publication of full details must therefore be deferred, but it may be mentioned that the Upper Carboniferous rocks penetrated at Bere Farm and Folkestone correspond in their lithological characters to the Upper Series of Mr. H. Bolton's classification[1] of Kent Coal Measures, while the beds which overlie the Carboniferous Limestone at Elham undoubtedly belong to the Lower Series.

The Bere Farm Boring.

This borehole was situated in a field on the east side of the Dover–Deal road, about $1\frac{3}{4}$ miles north-east of Dover. In the year 1913 operations commenced in the Chalk at a height of 396 feet above O.D., and concluded in November, 1915, after reaching a depth of 3,005 feet. Considerable portions of the hole were punched through down to the base of the Gault, which was reached at a level 954 feet from the surface, and excepting that nearly the whole of the Oxford Clay was passed through by punching, a fairly continuous series of cores was made throughout the remaining portion of the section. The dip as judged by the cores is generally low, but on several levels varied between 15° and 25°. The limits assigned to the Chalk-Gault and Oxford Clay are based solely on information obtained from the log-book of the boring.

	Thickness. Ft.	In.	Depth. Ft.	In.
Clay	5	6	5	6
Chalk and Chloritic Marl	825	6	831	–
Gault Clay	123	–	954	–
Folkestone and Sandgate Beds (partly estimated)	62	–	1,016	–
Atherfield Clay	22	–	1,038	–
Weald Clay	35	–	1,073	–
Hastings Beds (partly estimated)	7	–	1,080	–
Corallian Limestone	1	–	1,081	–
Lower Corallian	79	–	1,160	–
Oxford Clay	80	–	1,240	–
Kellaways	23	–	1,263	–
Cornbrash	18	–	1,281	–
Forest Marble	10	–	1,291	–
Great Oolite	67	–	1,358	–

[1] H. Bolton. 'The Fauna and Stratigraphy of the Kent Coalfield.' *Trans. Inst. Mining Engineers*, 1915, vol. xlix, p. 643.

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures (1,647 ft.)	Sandy shale and bind with a thin sandstone at top	92	–		
	Coal	–	10	1,450	10
	Hard black shale	4	6		
	Coal	–	10	1,456	2
	Hard black shale	78	–		
	Coal	–	3	1,534	5
	Hard black shale	55	–		
	Coal	–	10	1,590	3
	Hard black shale and hard grey sandstone	109	–		
	Coal	2	4	1,701	7
	Hard sandy shale and fireclay ...	65	–		
	Greyish-white quartzose sandstone, irregularly bedded and micaceous in places. Some pebbly courses...	94	5		
	Dark fireclay with stigmarian rootlets	7	–		
	Dark grey shales with *Neuropteris* ...	123	4		
	Coal	1	8	1,993	–
	Dark grey shales	27	–		
	Whitish-grey thin bedded micaceous sandstones with bands of dark grey shale	35	–		
	Dark grey and black shale with *Alethopteris* and *Neuropteris* ...	60	2		
	Coal	–	4	2,115	6
	Hard dark grey sandy shales with thin beds of whitish-grey sandstone near top	52	6		
	Hard grey sandstones with coaly films. Sandstones gritty at base, and contain numerous pebbles of coal and ironstone with *Neuropteris*	77	–		
	Grey shales, resembling fireclays in places, with numerous Stigmarian rootlets	64	6		
	Hard fine grained sandstone with coaly films	23	6		
	Dark grey and black shales with a bed of fireclay	27	–		
	Fine grained grey sandstone with a thin shale band	40	–		
	Dark brown fireclay with *Stigmaria*	7	–		
	Coal	–	3	2,407	3
	Dark brown fireclay passing below into dark micaceous shales with Stigmarian rootlets...	39	9		
	Hard grey sandstones with coaly films. Thin courses of conglomerate at 2,520 ft. and 2,541 ft. ...	100	–		
	Dark grey shales with thin micaceous sandstones	49	10		
	Coal	–	2	2,597	–
	Dark grey shales with a thin sandstone. Stigmarian rootlets abundant on many levels	193	–		
	Hard grey sandstone, micaceous in places...	20	–		
	Dark grey shales and fireclay ...	12	–		

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures (1,647 ft.)	Thin bedded dark grey micaceous sandstone passing below into hard grey quartzose sandstone with a 1 ft. band of conglomerate at 2,905 ft., containing pebbles of chert	86	–	2,908	–
	Dark grey shales with a thick bed of dark grey sandstone	38	6		
	Coal	–	10	2,947	4
	Dark grey fireclay with rootlets ...	2	8		
	Hard grey sandstones with thin pebbly courses at 2,980 ft. and 2,994 ft. containing pebbles of bright and dull coal	55	–	3,005	–

In the Cretaceous Group cores were available for the lower members only, and several had crumbled down, but sufficient details were secured to determine the existence of the sub-divisions mentioned. The only representatives of the Hastings Beds examined were some coarse sands which lay in pockets in the Corallian Limestone. From the Corallian Limestone to the base of the Great Oolite the sequence appeared to be complete, and all the formations yielded characteristic fossils, excepting the Oxford Clay, of which there were no cores. At the top of the Great Oolite the dip was 15°, but lower down it resumed the usual gentle angle. Lias was absent, and the Great Oolite rested directly on the Palæozoic floor.

A continuous series of cores was made in the Coal Measures, and all were available for inspection except some of the highest beds which were examined by Dr. E. A. N. Arber. The abundance of Stigmarian rootlets was notable in the argillaceous sediments, and many typical fossil plants were obtained, but no marine shells. The sandstones resembled those passed through at Folkestone, and there were also numerous courses of conglomerate with pebbles of coal, rolled fossiliferous ironstone-nodules, and fragments of dark chert.

The Elham Boring.

This borehole was situated in a field on the east side of the railway about 150 yards north-east of Elham station. Operations were commenced early in the year 1914 at a height of 275 feet above O.D., and ceased in June of the following year, after reaching the depth of 2,346 feet. Much of the boring was made by punching, but down from a depth of about 1,400 feet a nearly continuous series of cores was drawn. Above that level, in the absence of cores, thicknesses were estimated from the log-book.

	Thickness. Ft.	In.	Depth. Ft.	In.
Clay	3	–	3	–
Chalk and Chloritic Marl	287	–	290	–
Gault Clay	116	–	406	–
Folkestone, Sandgate and ? Hythe Beds	130	–	536	–
Atherfield Clay	30	–	566	–
Weald Clay	80	–	646	–
Hastings Beds	73	–	719	–
Kimmeridge Clay [partly estimated]	199	–	918	–
Upper Corallian	78	–	996	–

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		Thickness. Ft.	In.	Depth. Ft.	In.
Corallian Limestone [partly estimated]		129	–	1,125	–
Lower Corallian [partly estimated]		45	–	1,170	–
Oxford Clay		130	–	1,300	–
Kellaways, Cornbrash, and Forest Marble		68	–	1,368	–
Great Oolite, with ? Inferior Oolite at base [partly estimated]		131	–	1,499	–
Lias, including Upper, Middle, and Lower		99	–	1,598	–
Coal Measures (691 ft.)	Grey sandstones with thin bed of shale near base. *Sigillaria* ...	65	–		
	Dark grey micaceous sandy shales with thin beds of fireclay	91	–		
	Grey micaceous shaly sandstones with thin fireclay. Shales at base ...	68	–		
	Coal	1	8	1,823	8
	Dark grey shales with thin bed of fireclay, and thin-bedded micaceous sandstone. Stigmarian rootlets abundant	40	10		
	Coal	–	4		
	Fireclay	–	8		
	Coal	2	–	1,867	6
	Dark grey shales with Stigmarian rootlets	58	10		
	Coal	3	2	1,929	6
	Dark grey shales with 4 ft. band of muddy micaceous sandstone ...	21	10		
	Coal	2	8		
	Dark grey shales with Stigmarian rootlets	13	–		
	Coal	1	–	1,968	–
	Dark grey shales	11	–		
	Hard grey sandstones with partings of shale	21	–		
	Dark grey and blackish shales with lenticles of sandstone	13	–		
	Coal	1	4	2,014	4
	Dark grey sandy micaceous shale with thick beds of fireclay	69	8		
	Dark grey sandstone with pebbles of shale. Bed of sandy micaceous shale near base	33	–		
	Dark grey shales	36	–		
	Coal	1	10	2,154	10
	Dark grey shales with thin bedded micaceous sandstone at top ...	12	2		
	Coal	1	6	2,168	6
	Dark grey shales with thin bed of fireclay	11	–		
	Coal	1	3		
	Thick bed of brownish-grey fireclay passing below into grey shales with lenticles of sandstone ...	25	3		
	Coal	1	5	2,207	5
	Dark grey sandy micaceous shales...	30	7		
	Black fine-grained bituminous limestone	3	–		
	Grey and black shales with thin bands of sandstone	40	–		
	Grey micaceous shaly sandstone with *Stigmaria* and an irregular lump of black chert (pebble?)	8	–	2,239	–
Carboniferous Limestone (57 ft.)	Dark grey bituminous limestone with thin beds of "china-stone." Corals and brachiopods abundant	57	–	2,346	–

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No specimens of the Cretaceous rocks were available, but particulars concerning the formations between the Hastings Beds and the Corallian Limestone, and also from a level in the Great Oolite Limestones down to the base of the Lias, were secured. A large series of characteristic fossils served to determine the horizons with precision. As at Folkestone, there was no observable discordance at the junction of the Mesozoic rocks with the Coal Measures; the bedding of the two appeared to be parallel.

The Coal Measures consisted mainly of dark shales with a few beds of grey sandstone, and contained several seams of coal. The shales yielded numerous plant-remains, and occasionally poorly preserved shells of lamellibranchs, but none of marine species. Near the base a 3-feet bed of black fine-grained limestone was passed through. It contained no fossils, but was underlain by grey and black shales with *Alethopteris* and Stigmarian rootlets. In the lowest beds of the measures there lay imbedded a large irregular lump of black chert, apparently derived from the Carboniferous Limestone. It is surrounded by a thick coating of iron pyrites.

The Carboniferous Limestone was represented by dark grey bituminous limestones with smooth fine-grained beds, or 'chinastones.' On several levels the rocks were highly fossiliferous, and contained numerous specimens of corals, poorly preserved owing to replacement by crystalline calcite. The fossils include: *Lithostrotion martini* (Edw. and Haime), *Syringopora sp.*, *Chonetes sp.* [papilionaceous form], *Productus* cf. *corrugatus* (McCoy), *Productus sp.*, *Spirifer sp.*, and several indeterminable species of gasteropods. The rocks are of Visean age, and probably represent the upper part of the Seminula Beds or the lower part of the Dibunophyllum Zone.

The Folkestone Boring.

This borehole was situated in a disused brickyard near the southernmost Martello tower overlooking East Wear Bay. Towards the end of the year 1915 boring commenced in Gault Clay at a height of about 113 feet above O.D., and ceased in December, 1916, after reaching a depth of 3,400½ feet. The dip of the Coal Measures varied from 5° to 15°. Much of the boring was punched, and the thickness of the Cretaceous and Jurassic rocks above the Lias could only be estimated by help of the notes in the log-book.

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Gault Clay	85	–	85	–
Folkestone, Sandgate and ? Hythe Beds	210	–	295	–
Atherfield Clay	40	–	335	–
Weald Clay	165	–	500	–
Hastings Beds	53	–	553	–
Kimmeridge Clay [partly estimated]	210	–	763	–
Upper Corallian	123	–	886	–
Corallian Limestone [partly estimated]	123	–	1,009	–
Lower Corallian	81	–	1,090	–
Oxford Clay	172	–	1,262	–
Kellaways, Cornbrash, and Forest Marble	38	–	1,300	–
Great Oolite with ? Inferior Oolite at base	75	–	1,375	–
Lias	112	–	1,487	–

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures 1,913½ ft.	Grey sandy micaceous shales and binds, with a thick dark grey shaly sandstone at base. *Sigillaria* ...	27	–		
	Hard grey quartzose sandstone with thin gritty and pebbly bands. Numerous large rounded pebbles of coal	30	–		
	Dark grey shales with a thick bed of grey shaly micaceous sandstone. *Neuropteris* and *Calamites* abundant	91	6		
	Coal	–	3	1,635	9
	Dark grey shales with a thick bed of grey sandstone with shaly partings	38	9		
	Coal	2	–	1,676	6
	Dark grey and black shales with ironstone nodules. *Alethopteris* ...	49	6		
	Coal	1	2	1,727	2
	Hard grey shaly sandstone with carbonaceous films	18	10		
	Grey sandy shales with thin shaly sandstones. Lamellibranchs ...	142	–		
	Fine grained dark grey shaly sandstone	46	–		
	Grey sandy shales with thin grey sandstones	102	–		
	Coal	–	7	2,036	7
	Smooth grey sandy shales	36	5		
	Coal	–	8	2,073	8
	Grey sandy shales with thin sandstones	37	4		
	Grey gritty quartzose sandstone. Between 2,122 ft. and 2,129 ft., and and at 2,150 ft. sandstone contains numerous pebbles of coal and shale	42	6		
	Lumpy greenish-grey shales, red in places, with sandy micaceous bands	86	6		
	Grey sandy shales with a thick bed of shaly sandstone. *Neuropteris* and lamellibranchs common ...	51	–	2,291	–
	Hard fine-grained grey sandstone passing down into hard grey quartzose sandstones with 6-in. courses of conglomerate at 2,420 ft. and 2,426 ft. Pebbles of quartz, chert, shale, &c.	182	–		
	Grey sandy shales and a thin bed of fireclay	13	–		
	Coal	1	2	2,487	2
	Dark grey shaly sandstone, passing below into a hard whitish-grey speckly sandstone with three thin bands of grey sandy shales ...	146	10		
	Dark grey and black shales. *Neuropteris*	24	–		
	Hard dark grey sandstone with coaly films	92	–		
	Dark bluish-grey and grey shales with two thick bands of shaly sandstone	76	–		
	Hard grey fine-grained sandstone ...	43	–		
	Grey and black shales	168	–		

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures 1,913½ ft.	Hard grey fine-grained sandstone ...	58	–		
	Dark grey shales	7	–		
	Coarse grey gritty sandstone passing below into fine-grained grey sandstone. Brownish-grey fireclay at base	16	–		
	Hard grey gritty sandstones. Pebbles of coal at 3,180 ft.	172	–		
	Dark grey shales and thin beds of fireclay with a 12-ft. band of grey sandstone	110	6	3,400	6

For the reason stated we were not able to examine the strata between the Gault Clay and the lower part of the Kimmeridge Clay, or those between the Corallian Limestone and the Lias. Such cores as there were, however, of the Jurassic rocks yielded characteristic suites of fossils. There was no obvious discordance at the junction between the Mesozoic and Palæozoic rocks; the Lower Lias rested on a smooth irregular surface of the Coal Measures.

A continuous series of cores was available in the Coal Measures. The grey shales yielded plant-remains, and on several levels lamellibranchs were abundant, but no marine forms were found. The thick group of shales which were passed through between the depths of 2,153½ feet and 2,240 feet are noticeable on account of the presence of thin mottled red bands at two levels. When wet, the beds were generally of an olive-green hue, and they broke into lumps with a marly cuboidal fracture. Similar rocks do not appear to have been recorded hitherto in the Coal Measures of Kent. Thick beds of hard grey quartzose sandstone formed a characteristic feature in the cores, and several of them contained courses of conglomerate loaded with pebbles or subangular fragments of hard bright coal. Thin bands of conglomerate also occurred in a group of sandstones at 2,420 feet and 2,426 feet from the surface, and yielded pebbles of quartz, black shale, chert, and jasper. Microscope-sections of the chert show abundant remains of Foraminifera.

APPENDIX III.

On a Deep Boring made in 1907-9 at Battle.

By G. W. Lamplugh, F.R.S.

This boring was briefly referred to in the 'Summary of Progress for 1910,' p. 63, and a short abstract of the section was given in the 'Water Supply of Sussex (Supplement),' p. 243 (1911, *Mem. Geol. Surv.*), but the particulars have not hitherto been published.

The boring was carried out in 1907–1909 for the South-eastern Development Syndicate, Ltd., to whom we are indebted for access to the cores and journal. The site is 1,650 yds. N.N.E. of Battle Church, in a field at the S.W. side of Petley Wood

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(6-inch Ordnance Map, Sussex, 43 S.E.; 1-inch New Series, Sheet 320), at a height of about 120 ft. above O.D. The boring reached a depth of 2,066 ft. from the surface; it is $2\frac{3}{4}$ miles E.S.E of the old 'Sub-Wealden borings'[1], one of which attained a depth of 1,905 ft.; but a fault (shown on the Geological Survey Map, Old Series, Sheet 5), with a south-westerly downthrow, runs between the two sites and brings in at least 600 ft. of higher strata at the new boring. Therefore, although the last boring was the deeper of the two, the Sub-Wealden boring reached nearly 500 ft. lower in the stratigraphical sequence.

The cores of the recent boring ranged in diameter from $8\frac{1}{2}$ inches near the top of the section to 3 inches at the bottom, and were practically continuous. When examined by us in 1909 most of them had been exposed to the weather, with the result that the softer clays and shales had crumbled badly, and only the bands of firmer rock had remained intact. Therefore only a comparatively incomplete set of the fossils was obtainable; but there was not much difficulty in determining the composition and sequence of the strata.

The following section has been based mainly on this personal examination of the cores; some of the details, however, have been abstracted from the journal of the boring.

Section of Wealden and Upper Jurassic Rocks at Battle.

			Thickness. Ft.	Depth. Ft.
Wealden: (Hastings Beds), 424 ft.	Ashdown Sand, 184 ft.	Soil	2	
		Weathered clay with sandstone, and blue sandy clay	14	
		Soft pale sandstone	13	
		Dark and light marly clay	23	
		Pale sandstone	15	
		Marly clay with 4-ft. band of sandstone and 7-in. hard band	37	104
		Pale sand and sandstone with a gravelly band and some marly beds	80	184
	Fairlight Clays, 240 ft.	Pale sandy clay	35	
		Pale and dark grey shaly sandstone, with bands full of plant-remains	41	
		Red and variegated marly clay and pale clay	9	
		Alternations of shaly sandstone and sandy clay, with some bands of fresh-water shells (*Cyrena*; *Viviparus*, etc.)	76	
		Grey or bluish sandstone, mostly shaly	79[2]	424

[1] Several accounts of these borings have been published; *see* H. B. Woodward, 'Jurassic Rocks of Britain,' vol. v., *Mem. Geol. Surv.*, 1895, pp. 345–7; and W. Whitaker, 'Water Supply of Sussex,' *ibid.*, 1899, pp. 55–70.

[2] In the summary of the section previously published ('Water Supply of Sussex (Supplement),' p. 244), the base of the Hastings beds was taken at 345 ft., the 79 ft. of shaly sandstone being reckoned as part of the Purbeck beds. The amended classification here proposed brings the section into closer correspondence with the method of division for the beds at outcrop, adopted in the memoir 'The Geology of the Weald.' There is, however, no sharp line of division between the Wealden and the Purbeck beds.

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		Thickness. Ft.	Depth. Ft.
Purbeck beds, 387 ft.	Dark grey and greenish marly clay with bands of sandy shale and pale sandstone	35	
	Grey marly clay with bands and nodules of limestone	16	
	Alternations of dark silty shale, sandy shale and clayey shale, and greenish clays, with bands and nodules of ironstone, pale layers crowded with white fresh-water shells, *Cyrena media* (J. de C. Sow.), etc., and thin impure limestone... ... ... about	135	610
	Dark hard calcareous shale with some bands of marine or estuarine shells, including *Ostrea distorta* J. de C. Sow., *Corbula* cf. *inflexa* Sandb., *Protocardia?* etc. ... ... about	15	625
	Alternations of dark calcareous clay and clay-stone, sandy shale and impure sandstone, greenish marly clays and thin bands of clayey limestone ... ... about	139	764
	Gypsiferous beds. Calcareous shale and flaggy claystone veined and banded with gypsum ...	15	
	Impure gypsum with shaly partings ...	12	
	Gypsum with thin shaly bands	6	
	Hard yellowish gypsiferous cement-stone with irregular lumps and veins of white gypsum	14	811
Portlandian, 141 ft.	Yellowish-grey soft dirty sandstone, massive in structure, with obscure dark casts of fossils and wispy markings like fucoids; in the lower half, some harder slightly calcareous bands containing better preserved fossils; strong bituminous odour in some of the softer beds. *Trigonia gibbosa* J. Sow., *T.* cf. *incurva* Benett, etc.	71	882
	Darker muddy sandrock or sandstone with hard calcareous bands, and intercalations of sandy shale with clay-stone nodules; strong bituminous odour prevalent; the shales become predominant downward and form an insensible passage into the Kimmeridge clay. '*Holcostephanus*' *sp.* [fragment], *Ostrea* cf. *bononiae* Sauv., *Perna sp.*, *Rhynchonella sp.*...	70	952
Kimmeridge Clay, 1,114 ft. proved.	Upper Kimmeridge. Dark clay-shale, more or less marly, with some beds of 'papery' shale full of crushed fossils, and a few thin bands of hard splintery claystone. Cores much weathered. *Lingula ovalis* J. Sow., *Orbiculoidea latissima* (J. Sow.), *Protocardia morinica* (de Lor.), *Modiola autissiodorensis* (Cott.), *Aporrhais* cf. *piettei* (Buvign.) *Astarte spp.*, *Pinna sp.*	247	1,199
	Indurated marly clays with few fossils, and hard splintery claystones veined in places with calcite, alternating with thick bands of shaly clay full of fossils, and with some thin bands of platy bituminous shale. Fossils, same as last; also *Harpagodes sp.*, *Corbula sp.*, etc.	232	1,431

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			Thickness. Ft.	Depth. Ft.
Kimmeridge Clay, 1,114 ft. proved.	Virgula beds.	Dark muddy sandstone, mottled with carbonaceous matter, merging in places into sandy shale with lumpy and crumpled bedding. *Exogyra virgula* (Defr.)	41	1,472
		Marly clays with shelly layers. *Exogyra virgula* (Defr.)	57	1,529
		Palish-grey and mottled muddy sandstones and sandy shales, in parts calcareous. *Exogyra virgula* (Defr.), *Gervillia kimmeridgensis* (d'Orb.) ...	54	1,583
		Marly and shaly clays, with a few hard calcareous bands; few fossils obtainable as most of the cores were crumbled by weathering. *Exogyra virgula* (Defr.), *Astarte sp.*, *Pecten* (*Camptonectes*) *sp.*, *Pleuromya sp.*, fragments of ammonites	137	1,720
		Dirty grey sandstones and sandy shales, with occasional intercalations of clay-shale; some of the sandy beds calcareous and hard, others semi-coherent sandrock, mottled with tubular markings (? due to boring organisms); the fossils include casts of large bivalves in the upright position of life	50	1,770
		Marly and shaly clays with a little sandy shale; cores nearly all crumbled. *Exogyra virgula* (Defr.), *Anomia* cf. *suprajurensis* Buvign., fragments of ammonites...	169	1,939
		Fine-grained sandy limestone and clayey calcareous sandstone, banded with shale; good cores. *Exogyra virgula*? (Defr.)	8	1,947
		Calcareous shales, slightly sandy in places, banded and intermingled with hard clayey limestone and nodular cement-stone; good cores. *Exogyra virgula*? (Defr.), *Pinna granulata* J. Sow., *Pholadidea* cf. *compressa* (J. de C. Sow.), *Pleuromya sp.*, *Lingula ovalis* J. Sow., *Rhynchonella sp.*, *Terebratula sp.*, *Serpula sp.*, *Cidaris* (spine), '*Holcostephanus*' aff. *stephanoides* (Oppel)	119	2,066
		Bored, but core not drawn	5	2,071

The bottom beds are probably close to the base of the Kimmeridgian series, if not actually within the Upper Corallian.

The particular interest of this boring is in the means it affords for comparing the Upper Jurassic sequence on the southern side of the Wealden dome with that which was proved by the boring at Penshurst, near Tonbridge, on the northern side.[1]

Both borings began not far below the top of the Ashdown Sand, and both, after passing through the entire Purbeck and Portland series, terminated in Kimmeridge Clay. But while the Battle boring reached nearly, if not quite to the base of the Kimmeridge series, the Penshurst boring stopped before reach-

[1] 'On the Mesozoic Rocks in some of the Coal Explorations in Kent.' *Mem. Geol. Surv.*, 1911, pp. 66–77.

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ing the Virgula Beds which form the lower and larger part of the Kimmeridge Clay. A comparison of the thickness of the formations proved at the two places is shown in the following table:—

—	*Battle*, 120 ft., O.D.		*Penhurst*, 85 ft., O.D.	
	Thick-ness.	Depth.	Thick-ness.	Depth.
	Ft.	Ft.	Ft.	Ft.
Wealden, from near top of Ashdown Sand	424	424	552	552
Purbeck beds	387	811	562	1,114
Portland beds	141	952	131	1,245
Upper Kimmeridge Clay...	479	1,431	622	1,867
Lower Kimmeridge Clay...	635	2,066		

In respect to the Wealden beds, the comparison may not carry much weight, as this series is variable and merges insensibly downward into the Purbeck beds. But the base of the Purbeck is a sharp boundary, and the Virgula beds of the Kimmeridge Clay are also definite. It is certain, therefore, that the Upper Jurassic formations in the aggregate are thinner at Battle than at Penshurst by at least 300 ft., and that these rocks on the southern side of the dome sink northward towards Penshurst. This structure is complementary to that on the northern side of the dome where, as the borings in Kent have proved, there is a great southward thickening of the same rocks and of the deeper Jurassic formations accompanied by a southerly dip.[1] As was pointed out in the memoir above cited, the effect of this structure is that the Wealden anticline of the Cretaceous rocks is superimposed upon a buried syncline of the Jurassic rocks. The present boring yields confirmatory evidence for the buried syncline.

The average northerly inclination of the Jurassic planes of division between Battle and Penshurst indicated by the table is locally reduced by the previously-mentioned fault; if the levels of the same planes in the old Sub-Wealden borings on the upthrow side of the fault be taken for the comparison, the dip becomes accentuated.

The position of the deepest part of the buried syncline has not yet been proved; it probably lies nearer Penshurst than Battle.

If compared with the records of the same formations in the Sub-Wealden borings, the present record will be found to differ in many points of lithological detail. These discrepancies may arise mainly from the doubtful determination of some points in the Sub-Wealden section as compiled from various separate records.

[1] See pp. 45-52 of present 'Summary'; also previous memoir 'On the Mesozoic Rocks, etc., in Kent,' *supra cit.*

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APPENDIX IV.

The Underground Range of the Jurassic and Lower Cretaceous Rocks in East Kent.

By G. W. Lamplugh, F.R.S.

Since the publication of the Geological Survey Memoir on 'The Mesozoic Rocks in some of the Coal Explorations in Kent' in 1911, the officers of the Survey[1] have had opportunities[2] for examining the cores of the Mesozoic rocks from most of the numerous borings which have been made in Kent. A summary of the information obtained may now be given.

Almost all the new borings lie farther north than those previously described, and are therefore in the region where the sequence of Mesozoic rocks is shorter and less nearly complete than in the Brabourne and Dover sections already dealt with. They are sufficiently numerous to bring out clearly the underground range of the various formations proved in the older borings, and incidentally to confirm the deductions as to the underground structure which were stated in the memoir referred to. The unexpected fact that in this district the Palæozoic floor is reached at a less depth beneath the highest outcropping formation (Eocene) than beneath the lowest (Wealden) is explained mainly by the disappearance northward of all the Oolitic formations in turn, under the Cretaceous unconformity, and the similar disappearance of the Lias under the unconformity of the Oolites. As a result of the borings we are able to fix the position of the ancient outcrops of the formations beneath the unconformities and approximately to trace their hidden boundaries. This information is likely to be of practical service where mining operations are contemplated.

The structure of the concealed Jurassic rocks in this area proves to be comparatively simple. If all the Tertiary and Cretaceous formations could be stripped off from the country south of the Stour valley (and the sea excluded) a broad smooth slope would be laid bare, descending nearly north-eastward from the Folkestone–Ashford area to the tract under the present Stour at a rate diminishing from about 40 feet per mile in the south to 20 ft. or less in the north; and across this slope the outcrops of the successive formations from the Great Oolite upward to the Portlandian would be found to stretch in parallel belts striking, with slight irregularity, west-north-westward from the line of the present coast. The Lias would still remain hidden by the unconformable overlap of the Lower Oolites; but its course is nearly, though not quite, parallel to that of the other Jurassic formations. The strike of these belts is nearly the same as that of the Cretaceous rocks now seen at the surface, but

[1] The material from the borings has been examined at the sites by the writer and Mr. J. Pringle, the fossils have been determined in the Palæontological Department of the Survey by Dr. F. L. Kitchin and Mr. J. Pringle.

[2] We are particularly indebted to Dr. Malcolm Burr and to Mr. E. O. Forster Brown for access to the many borings respectively under their charge.

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their dip, though slight, is diametrically different, being southerly instead of northerly, so that if they were at the surface their escarpments would face in the opposite direction to that of the Chalk.

The relative underground positions and approximate boundaries of the Jurassic belts in north-east Kent are shown diagrammatically in Fig 2; and the structure, down to the Palæozoic floor, is illustrated by the section forming Fig. 3.

The salient characters and stratigraphical relations of the several formations, in ascending sequence, are as follows.

Lias.—The northward limit of the Lias is nearly coincident with the main railway-line between Canterbury and Dover, and the formation has been proved in all the East Kent borings south-west of that line. Its thickness diminishes steadily from 140 ft. in the south-west (Brabourne) to less than 15 ft. near its northern margin, partly through the thinning of its individual members and partly through the shaving down of its top before the deposition of the Lower Oolites. But even in some of the borings where thinnest (Fredville, 13½ ft.; Bishopsbourne, 22 ft.; Chilton, 25ft.), the presence of beds belonging to the three major subdivisions, Upper, Middle, and Lower Lias, has been proved by the evidence of fossils.

The Upper Lias consists mainly of smooth clay-shale; the Middle Lias, of alternations of shale, hard shelly limestone and calcareous sandstone, occasionally rather ferruginous; the Lower Lias, mainly of clay-shale and sandy-shale with a few thin limestone-bands. The occurrence of a conglomeratic band in the Middle Lias at Chilton suggests the neighbourhood of a shore to the northward, and it is probable that the Palæozoic rocks were above sea-level during part of the Liassic period in the north-eastern corner of the area shown in Fig. 2.

The Trias, proved in the older boring at Brabourne,[1] is absent from all the borings examined to the northward and eastward; and the Lias wherever present in the newer borings is found to rest directly upon a freshly-eroded and unweathered surface either of the Coal Measures or still older rocks.

Lower Oolites.—The Lower Oolites are the last portion of the Jurassic sequence to be cut out northward by the Lower Cretaceous unconformity, and they therefore occupy a larger area underground in East Kent than any other division of the Jurassic system. In the west, their northward termination probably lies well within the Tertiary area, about 3 miles north of Canterbury, but, striking east-south-east, leaves this area before Sandwich is reached, and curves south-eastward into the Chalk country a mile or two west of Deal, evidently controlled by the shape of the rising Palæozoic platform.

In the borings nearest this northern margin the Lower Oolites appear to range from about 20 ft. to about 40 ft. in thickness, and to consist mainly of the Great Oolite limestone; but the method of boring has yielded only imperfect evidence. Southward and westward from the margin the division increases steadily in thickness, until at Brabourne, in the

[1] *See* 'Mesozoic Rocks in some of the Coal Explorations in Kent.' *Mem. Geol. Surv.*, 1911, pp. 51–54.

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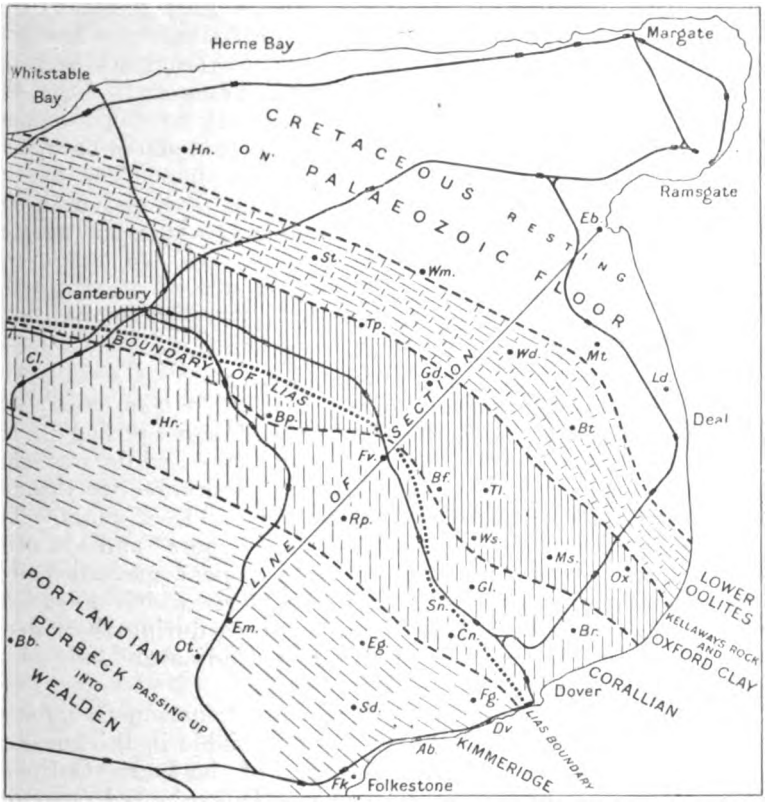
Fig. 2.—Sketch-map showing range of buried Jurassic formations in East Kent.



Scale of Miles

0 5 10 15

Railways, with position of stations, shown by continuous black lines.

Borings (and shafts) from which information has been obtained, indicated by black dots, lettered as follows:—

Ab., Abbotscliff.	Fg., Farthingloe.	Rp., Ropersole.
Bb., Brabourne.	Fk., Folkestone.	Sd., Lower Standen.
Bf., Barfreston.	Fv., Fredville.	Sn., Stone Hall.
Bp., Bishopsbourne.	Gd., Goodnestone.	St., Stodmarsh.
Br., Bere Farm.	Gl., Guildford (shaft)	Tl., Tilmanstone (shafts).
Bt., Betteshanger.	Hn., Herne.	Tp., Trapham.
Cl., Chilham.	Hr., Harmansole.	Wd., Woodnesborough.
Cn., Chilton.	Ld., Lydden Valley.	Wm., Walmestone.
Dv., Dover (shafts).	Ms., Maydensole.	Ws., Waldershare.
Eb., Ebbsfleet.	Mt., Mattice Hill.	
Eg., Ellinge.	Ot., Ottinge.	
Em., Elham.	Ox., Oxney.	

south-western corner of the area, it measures 194 ft. The belt in which the Lower Oolites form the floor immediately beneath the unconformable Cretaceous rocks has an average width of about 2 miles, but becomes narrower before reaching the present coast-line between Deal and St. Margaret's Bay (see Fig. 2).

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Stratigraphically and palæontologically, the development of the Lower Oolites in East Kent is similar to that in the South-west of England, and is unlike that in the East Midlands and Lincolnshire. In all borings where the full sequence was represented by adequate cores, it was possible to recognise the main subdivisions present in the South-west of England, from the Cornbrash downward to the bottom of the Great Oolite series; but the Inferior Oolite was identified in a few places only, and appears to be often absent and nowhere complete. The following are the subdivisions determined in the borings, with the range of their thickness, in round numbers, where not affected by the Cretaceous unconformity.

	Ft.
Cornbrash	10 to 20
Forest Marble	10 to 20
Great Oolite limestones	40 to 120
Great Oolite sandy beds, with part of Inferior Oolite in places	0 to 40

The bottom sandy beds are thickest and best marked in the borings farthest east; they thin out northward, while westward and south-westward they tend to lose their individuality through the intercalation of sandy limestones and bands of shale. The sands generally contain large calcareous 'doggers' and are often mottled with fragments of lignite; they pass unconformably across the Lias to the bare Palæozoic platform which must have suffered renewed erosion in the northern area during their deposition. They represent the scourings from adjacent land, swept off-shore and deposited in shallow-water.

The Great Oolite limestone is the most conspicuous member of the Lower Oolites, and also the most variable in thickness, so that most of the south-westward increase of the Lower Oolites is due to the swelling of these limestones. Its main beds are composed of pale massive oolite, usually of medium or close grain, and poor in fossils; but toward the north and east these become attenuated and split up by partings of clay-shale and oolitic rubble in which fossils are often abundant. The close-grained rock, if accessible, should make an excellent building-stone, a point worth mentioning in view of the fact that mining shafts have already been sunk through it and that more are in prospect.

The Forest Marble series and the Cornbrash are relatively minor subdivisions, and show comparatively little change in thickness within the area, being, if anything, slightly thicker in the north-eastern part of their range than elsewhere. Both are heterogeneous deposits, chiefly of marl and clay with irregular bands of limestone, calcareous sandstone and oolitic rubble. They are distinguishable mainly by their fossils, which are numerous, and by the presence of green clay and a peculiarly compact limestone in the Forest Marble.

Kellaways Rock and Oxford Clay.—Where pierced in the Kentish borings, the Kellaways Rock is readily identifiable by its composition and fossils, though there is sometimes difficulty in determining precisely its upper and lower limits. Its underground contact with the overlapping Cretaceous strata occurs in a narrow belt running E.S.E. from the neighbourhood of Canterbury to the coast near St. Margaret's. This belt is not wide enough to be shown separately in Fig. 2, and it is therefore

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united with the broader belt of the overlying Oxford Clay, the two together having a breadth ranging from about 1½ mile in east to about 3 miles in the west.

The Kellaways Rock appears to attain its greatest thickness about midway between Canterbury and the coast, 43 ft. being assigned to it in the Fredville boring, whereas farther east it drops to between 30 and 37 ft., and farther west to under 20 ft. (Brabourne and Harmansole). The differences may be in part due to the uncertainty as to its boundaries, but seem also to indicate some interchangeability of composition with the lower portion of the Oxford Clay, as in other parts of the country. In its lithological aspect, the Kellaways Rock shows much local variability; in the more southerly and south-easterly sections its chief component is an impure marly sandstone with some ferruginous beds, but inland and northward the main portion is a ferruginous marlstone, sometimes highly glauconitic. Much of the iron in this ferruginous rock is disseminated in round coffee-coloured 'millet-seed' grains; and it therein resembles the Upper Corallian iron-ore, though stated to be less rich in iron and to contain a larger proportion of deleterious matter. Its possible commercial value, however, deserves attention. In some of the borings, particularly Fredville, parts of the rock are so rich in glauconite as to be quite green in colour.

The Oxford Clay is the least variable of all the Kentish Jurassic deposits; wherever seen, it has consisted almost wholly of fine-textured marly clay without conspicuous bedding, and mostly of a palish grey-blue tint with some subordinate brown bands. It thickens rather rapidly westward from 88 ft. at Dover to 173 ft. at Brabourne, and about the same at Chilham, with intermediate values at points between these places.

Corallian Series.—The Corallian rocks have a strong development in the southern part of East Kent, their range including nearly all the tract south-west of the main road (Watling Street) between Dover and Canterbury. The thickness of the whole series, as ascertained in the Dover shafts, is 310 ft., and in the Brabourne boring 342 ft., so that the westerly expansion is not so marked as in most of the Jurassic formations. The beds probably become thinner northward, but owing to the incomplete state of the series in this quarter, comparison is difficult. The northern edge of the formation lies a mile or two south of Canterbury, and runs E.S.E. to the coast between Dover and St. Margaret's. This boundary appears to have a pronounced southward bulge near Bishopsbourne and a northward bulge between Fredville and Barfreston (see Fig. 2). These bends may denote faulting, or they may indicate that the thick limestones of the series have an irregular escarpment buried under the Wealden deposits. The average width of the Corallian belt beneath these deposits is about 3 miles.

The most characteristic and persistent portion of the Kentish Corallian series is the thick mass of pale coralline limestones which forms the middle part of the formation and has, in the south, a thickness of 125–135 ft. Both above and below these limestones the series consists mainly of clays, marls, marlstones and rubbly oolites with subordinate bands of impure limestone. In these beds there is frequently an admixture of ferruginous matter in the form of small coffee-coloured granules of iron-

oxide, which are in places segregated into bands of iron-ore like that of Westbury, in Wiltshire. The thickest of these bands occurs in the Dover district in the beds above the coralline limestones, and is likely to prove of economic value.

The separation of the Corallian from the Oxford Clay below and the Kimmeridge Clay above is largely dependent upon palæontological evidence. Fortunately, fossils are sufficiently abundant to define the boundaries within narrow limits.

Kimmeridge Clay.—The few additional borings which have pierced the Kimmeridge Clay have yielded hardly any material for examination. Fortunately the explorations previously described[1] gave full opportunity for the study of this formation, while the recent borings have sufficed to fix its underground range fairly closely (see Fig. 2).

Attention may here be called to the description on p. 40 of a deep boring near Battle, in Sussex, in which the Kimmeridge Clay was fully displayed, and the Portland and Purbeck beds also.

Portland and Purbeck Beds.—None of the Kentish borings recently examined lie within the range of these rocks.

Lower Cretaceous—Wealden and Lower Greensand.—Lower Cretaceous strata were passed through in all the borings examined with the doubtful exception of that near Herne; but cores were available in only a few instances. Fortunately several of the beds can be identified even from small chiselled chips; in particular, the glauconitic rock-band just below the Gault; the chocolate-brown bed in the Atherfield Clay; the cypridshales of the Weald Clay; and the sharp quartz-sands at the base of the Wealden.

The Wealden beds stretch well beyond the area covered by the Jurassic rocks in East Kent. In this quarter they probably continue nearly as far northward as the Lower Greensand, and the two appear to be practically conformable, though the Lower Greensand is known to overlap the Wealden beds in the north-western part of the county. Both formations are present at Ebbsfleet, and both are believed to be absent in the neighbourhood of Herne; but the evidence in this northern tract is as yet insufficient to define the boundaries of either formation. It is certain, however, that their strike is not quite the same as that of the Jurassic rocks or of the Gault.

The thickness of the Wealden series in the Ebbsfleet boring is only 15 ft., but it increases steadily southward to 85 ft. at Dover, and appears not to exceed this in any of the borings between Dover and Canterbury, with one doubtful exception (Chilton). To the south-westward of this belt the expansion must be more rapid, as the Brabourne boring proved 309 ft. of Wealden deposits. Even where thinnest, the series shows a change of character from sandy and silty beds in the lower portion to clayey and shaly beds in the upper portion; but these thin subdivisions can hardly be regarded as strictly equivalent to the thick masses of Weald Clay and Hastings beds that are seen in the Weald in similar relationship.

[1] 'Mesozoic Rocks,' *op. supra cit.*

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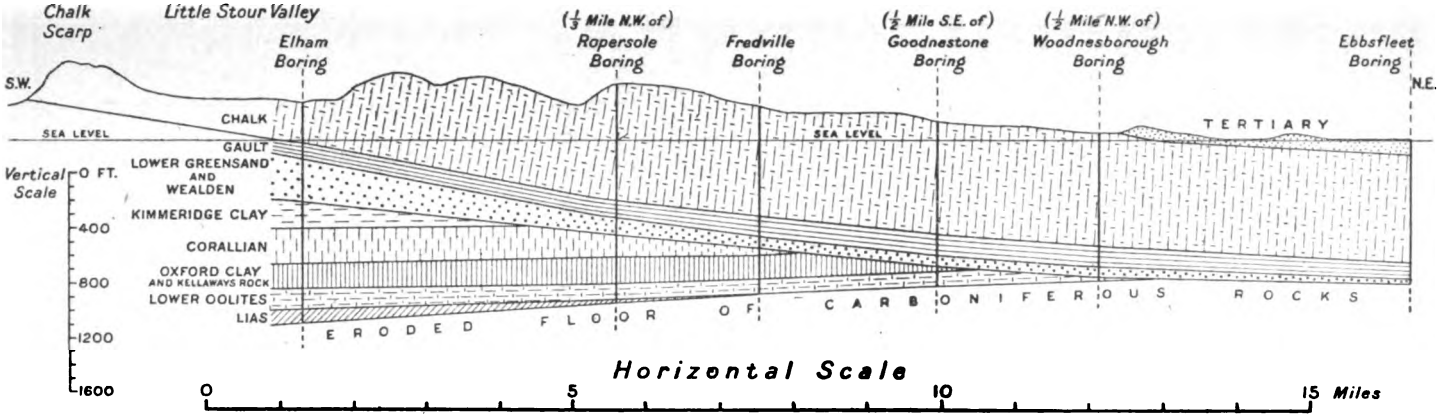
Fig. 3.—Section across East Kent, along the line shown in Fig. 2.

Vertical Scale 10 times the Horizontal Scale.



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The Lower Greensand appears to be less regular in thickness, though increasing as a whole southward and south-westward like the Wealden beds. At Ebbsfleet it is 36 ft. thick, but is apparently rather less than this at two or three places farther south, and not much thicker in certain borings to the westward. Nevertheless, on reaching Dover it has expanded to 130 ft., and at Brabourne it is 237 feet thick. The Atherfield Clay forms the lowest portion of the series over most of the area, but was not found in some of the north-easterly and north-westerly sections. In most places the greater part of the Lower Greensand consists of beds of the 'Sandgate' type—muddy and loamy glauconitic sands and clays—with a thin bed of coarser and cleaner glauconitic sand of 'Folkestone' type at the top, the uppermost portion of which is usually indurated into a concretionary band of hard calcareous glauconite-grit. No beds of the 'Hythe' type were found in any of the borings. The Atherfield Clay, where present, appears to have suffered some erosion before the 'Sandgate beds' were deposited, probably by current-action on a sea-bottom.

From the section forming Fig. 3 it will be seen that the Jurassic and Lower Cretaceous rocks together form a great wedge with a northward apex, intervening between the Palæozoic floor and the basal bed of the Upper Cretaceous. The N.N.E. dip in the Cretaceous rocks is thus changed to a S.S.W. dip in the Jurassic rocks, and the northern part of the great superficial anticline of the Weald is found to be superimposed upon a syncline of the deeper rocks. This structure was demonstrable from the evidence of the four early borings dealt with in the memoir already referred to, but it is brought out much more clearly by the later borings. The Battle boring described in preceding pages (pp. 40-44) shows that the Jurassic rocks rise southwards, and become thinner under the southern side of the Wealden dome.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1917.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1917.

I.—INTRODUCTION.

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

During the year 1917 the investigations of the resources of economic minerals which had been put in hand in previous years were continued. The main part of the field-work upon refractory materials having been completed, and the results so far written up as to enable a volume dealing with the occurrences and geology of the materials to be sent to the printer, an investigation of the iron ores of Great Britain was commenced. At the same time no opportunity was lost of examining the more important boreholes which were being made in search of coal, iron, oil, water, etc., both in England and Wales and in Scotland. In Scotland also some revision of the Carboniferous rocks in Lanarkshire was carried out for the purposes of the Memoir on Area VI. of the Central Coalfield, and additional information on some fireclays and sandstones in Ayrshire and Sutherlandshire was obtained.

Felspar, which was considered chiefly as a possible source of potash in 'Special Reports of the Mineral Resources of Great Britain,' Vol. V., has been the subject of much enquiry. Before the War most of the felspar used in Britain in the glass, enamel and pottery trades was imported from Sweden and Norway, and the difficulty of maintaining the supply under existing conditions has directed attention to our home resources, and necessitated further examination of the Scottish occurrences. This work was entrusted to Dr. R. Campbell, of the University of Edinburgh, who was appointed a temporary member of the staff for the purpose. Dr. Campbell's report will be found on pp. 30-34; it shows that there are several localities, not difficult of access, where felspar can be obtained in commercial quantities.

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Requests for reports on the geology of the alternative routes which are being considered for the Mid-Scotland Ship Canal have led to the collecting of additional information on the distribution of the superficial deposits and on the features of certain buried preglacial valleys. The results are summarised on pp. 34-36.

The boring near Market Weighton (p. 42), for the publication of which permission has now been kindly granted by Messrs. J. and T. Mitchell, and more recent borings at Bilsthorpe, Edingley, Farnsfield and Wellow, which have been under the observation of Dr. Gibson, have afforded much information on the structure of a part of the concealed Yorkshire and Nottinghamshire coalfield. The possibilities of the area, which extends from the Trent near Nottingham northwards to the Humber, were considered by the Royal Commission on Coal Supplies in 1901-05, but at that time the information was scanty. The chief results of later exploration, so far as regards their practical bearing, can be briefly summarised as follows.

The cover of Triassic and Permian rocks, by which the coalfield is concealed, increases in thickness eastwards at a constant rate. The increase and its uniformity are due to the eastward slope and uniform gradient of the floor upon which those formations rest. These characters were illustrated by the map forming Plate I. of the Concealed Coalfield of Yorkshire and Nottinghamshire, published in 1913. The correctness of the contour lines in the Palæozoic floor there shown is confirmed by recent explorations, and the lines can now be extended northwards, and eastwards to the 3,000 ft. level. The Trias and the Permian reach the greatest thickness yet proved, more than 3,000 ft., at Market Weighton, in a region where the Jurassic and Cretaceous formations are not only individually thin, but where the Upper Cretaceous overlaps several of the underlying subdivisions and comes to rest on the Lower Lias.

The basal bed of the Permian is composed of hard breccia south of Retford, but consists of shales or of unconsolidated sandrock north of Retford.

The eastern margin of the concealed Coal Measures lies near the Trent, and it is therefore doubtful whether the Top Hard (Barnsley) Coal, lying some distance above their base, extends so far as that river.

The Top Hard Coal, wherever it has been proved, shows changes in passing from one part to another of the concealed area, corresponding to those which it shows in the visible coalfield.

Some of the seams which lie above the Top Hard are of workable thickness in the concealed area. They may even, as in the case of the High Hazles or Kents Thick Coal, attain a greater thickness than in the visible coalfield.

The Upper Coal Measures, consisting chiefly of red marls and sandstones, survive only in the deepest parts of the syncline, and are confined to an area south of Retford. They are conformable to the Middle Coal Measures, but were extensively denuded before the deposition of the Magnesian Limestone Series. The

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depths to the Top Hard (Barnsley) Coal vary greatly in neighbouring explorations, and the existence of some powerful dislocations in the Coal Measures must be inferred. On this subject reference should be made to the account of the Kelham borehole, which forms Appendix III.

The increased demand for Tungsten Ores brought about by the war has led to important developments in Cornwall and Devon. Mr. Dewey reports that new lodes have been discovered and are being worked at Castle an Dinas near Roche, where a north and south-bearing lode in killas is said to assay 2 per cent. wolfram; at Hemerdon Tor near Plymouth, where a plexus of greisens in mineralised granite covers nearly 18 acres with a reputed reserve of a million tons of 2 per cent. ore; and at Kit Hill, Callington, where trenches have proved many lodes in the granite.

Parkanchy, an old mine, has been re-opened under Government subsidy; the south lode has so far proved satisfactory with assay values of 4 per cent. tin and wolfram. Some alluvial propositions on Bodmin Moor are being exploited on a large scale. The principal wolfram mines, South Crofty, East Pool and Tincroft, have increased their output of ore.

A magnetic survey of Great Britain, recently carried out by Mr. G. W. Walker, F.R.S., has disclosed the existence in certain parts of the country of disturbing forces, of which no explanation has as yet been found. It was suggested that the disturbances might be due to concealed masses of iron ores, and the matter was therefore laid for consideration before an Iron-ore Committee appointed by the Conjoint Board of Scientific Societies. The Committee formed an opinion that more detailed magnetic observations ought to be made in certain districts in which the disturbing forces had been observed, and that they should be accompanied by a petrological examination of the rocks, with a view to ascertaining what their magnetic effects might be. As a result two districts were re-examined by Mr. Walker, one near Melton Mowbray and the other near Irthlingboro'. In both cases questions of possible economic importance were involved, inasmuch as iron ores are being worked in the neighbourhood.

The carrying out of the petrological survey, which necessarily included both outcropping and deep-seated rocks, was undertaken by the Geological Survey, and the work was entrusted to Dr. A. H. Cox, who was appointed a temporary member of the staff in September, 1917, for the purpose. In the course of the autumn Dr. Cox collected representative specimens of the rocks accessible at the surface and was furnished by the Survey with specimens of those which were obtainable only from boreholes. The specimens have been examined as regards their petrological and chemical characters by Dr. Cox, and as regards their magnetic properties by Professor E. Wilson. A joint report by Mr. Walker, Prof. Wilson and Dr. Cox is in preparation.

On the subject of iron ores, as on other economic applications

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of geology, much information is scattered through various Geological Survey Memoirs.

The 'Iron Ores of Great Britain,' which was commenced in 1856, and of which four parts had been published by 1862, dealt with the Northern and North Midland Counties of England, South Staffordshire, South Wales and the Shropshire and North Staffordshire Coalfields. For precision and accuracy of analysis these records would be difficult to surpass, but they cover a part of the kingdom only, and leave untouched some of the areas from which a large proportion of our ore is now derived. The Mesozoic ores, which are abundant but of low grade, and the products of lodes, etc., are described in various memoirs for many but not all parts of the country. The active developments of recent years, however, have rendered it necessary to bring the information up to date for all regions. The field-work, therefore, has included an examination of existing workings, with a view to ascertaining the mode of occurrence, the characters and probable extensions of the deposits being worked.

The classification of the ores adopted is based upon the mode of occurrence. They fall into three classes, namely, those products, mostly Hematites, which occur in lodes, as replacements, etc.; the Mesozoic Ores which take their places in the sedimentary series as bedded calcareous or sandy strata with a varying proportion of the carbonates or oxides of iron; the Clay-ironstones which with Blackbands abound in the Coal Measures, and which have been worked also in the Wealden and Yoredale Beds of England. The Scottish ores, which range through the Coal Measures, Millstone Grit, the Upper Limestone group, the Limestone Coal group, and the Lower Limestone group belong to this class, with the exception of the Mesozoic ore of Raasay.

The field-work was completed before the expiration of the year. The Mesozoic ironstone works were examined by Mr. Lamplugh, Mr. Wedd and Mr. Pringle, under the superintendence of the first-named, who himself furnishes an account of the Cleveland district. Lincolnshire, Rutland, Northamptonshire, Hunts and Leicester were reported on by Mr. Wedd; Oxfordshire, Warwickshire, Wiltshire and Dorset, by Mr. Pringle. The reports on the Coal Measures and kindred ores (apart from those of South Wales), were prepared by Dr. Gibson, who was assisted in Staffordshire and Shropshire by Mr. Dewey, and in Northumberland by Dr. Sherlock. The various occurrences of hematites, etc., in lodes, etc. (apart from those of the Forest of Dean and South Wales) were investigated by Mr. Smith, Dr. Sherlock, and Mr. Dewey, under the superintendence of Mr. Cantrill. The hematite occurrences of Cumberland and Lancashire were examined by Mr. Smith, the lodes and occurrences of hematites and pisolitic ores in North Wales by Mr. Cantrill and Dr. Sherlock, the lodes of Cornwall and Devon by Mr. Dewey, and those of the Brendon Hills and Exmoor by Mr. Cantrill and Dr. Sherlock. At the same time an exhaustive examination of the hematite deposits of the Forest of Dean and of South Wales (with Monmouthshire) was in progress by Prof. T. F. Sibly, who had generously placed his services, and the knowledge of the Forest

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that he had already gained, at the service of the Geological Survey. This investigation is yielding results of great scientific and economic importance.

In Scotland the field-work on iron ores was carried out in Raasay and in Fife by Dr. G. W. Lee; in Midlothian, Haddington and the Coal Measures of Fifeshire by Mr. T. Robertson; in Ayrshire by Mr. G. V. Wilson; and in the Central Coalfield by Mr. M. Macgregor.

The difficult problem of estimating reserves in undeveloped ground involved a close inquiry into the geological conditions prevailing in and around the proved areas. It assumed its simplest form in the case of the bedded ores, such as those of the Mesozoic formations and the Coal Measures. The Mesozoic ores occur mainly in the Lower and Middle Lias, the Northampton Sands, the Corallian and the Lower Greensand. In each case the outcrop of the ore-bed can be traced, and the part of it which is workable determined. Its horizontal extent underground as a payable ore remained an uncertain factor, and this has been partly determined by recent mining exploration. As regards the Coal Measure ores also, which were once most important sources in South Wales, Staffordshire, Shropshire and elsewhere, the reserves are calculable, but the demand for the ores has so dwindled, chiefly in consequence of the competition from cheaper sources, that the labour involved in making detailed estimates of the undoubtedly great reserves is not justifiable in all cases. The Blackbands of North Staffordshire are exceptional.

As regards the reserves of hematite and other iron ores in lodes and pockets, the problem is far different. The productiveness of a lode, the extent of a pocket or the location of new pockets, are matters which it is impossible to predict with precision. A study of the conditions, however, under which the ores have been formed renders it possible to define, more or less closely, the areas in which further deposits are likely to occur. Thus in the case of the hematite deposits of Cumberland and Lancashire, the association of the ores with lines of fault, with certain beds of the Carboniferous Limestone cut by the faults, and lastly with the former distribution of the Permian and Triassic rocks, has been established over what may be called the visible ore-field. Other tracts where the Permian or Triassic rocks still exist, and where the Limestone may be inferred, on geological reasoning, to underlie them under suitable conditions, are regarded as concealed ore-fields. Estimates of their contents are made on the assumption that they contain ore in the same proportion as the ore-fields already worked.

In the Forest of Dean the chief ore-bodies occur in the upper part of the Carboniferous Limestone Series, which crops out round the greater part of the coalfield. By operations extending through several centuries their existence has been proved over a part of the outcrop, and for this part Prof. Sibly has found a calculation of reserves possible. On the other hand how far the ore-bodies extend, or whether they are equally abundant, beneath the coalfield, has not been ascertained, and for

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this concealed ore-field no estimate is attempted. It remains as a possible but unknown reserve.

In Glamorganshire the hematites occur in the upper part of the Carboniferous Limestone, and their formation here has clearly been dependent upon the former distribution of Triassic rocks. As in Cumberland and Lancashire there exists in Glamorganshire a visible ore-field, which has been partly exploited; and a field concealed by red rocks, as yet little exploited, but regarded by Prof. Sibly as being of considerable promise. Estimates of the reserves of the concealed field are founded on a consideration of the area over which suitable geological conditions extend, and on the assumption that the yield will be proportionate to that of the ground already worked.

The lodes offer a still more difficult case. Few are being worked, some having been worked out, others exhausted to water-level, but that several contain reserves of ore is certain. The estimate in such cases is founded on the assumption that, in the aggregate, the lodes contain a reserve of ore equal to the aggregate output of the last 10 years, or in some cases the last 20 years, of the mining operations. This basis, arbitrary as it is, leads to an estimate bearing some relation to the proved productiveness of past years.

The estimates of iron ores that have been made by the various methods described above are set out in the following table. They are, on the whole, framed in a cautious spirit, with an intention to avoid overstatement of reserves. Even so the reserves of all classes of iron-ore reach an enormous figure. It must be remembered, however, that a limiting factor on their development exists in the low value of ironstone. Low-grade ores, such as those of the Mesozoic rocks, command a price but little better than that of ordinary stone. In our present enquiry we have been concerned only with the quantities which exist; the quantity that can be profitably worked will depend upon future contingencies.

GREAT BRITAIN.

Hematites, etc.

	Reserves more or less developed. Tons.	Probable additional Reserves. Tons.
Cumberland and Lancashire	40,000,000	70,000,000
Durham (Weardale)	—	250,000
Gloucestershire (Forest of Dean)	2,500,000	—
South Wales (Llanharry District)	—	4,000,000
Cornwall and Devon	—	500,000
Somerset (Brendon and Exmoor)	—	250,000
North Wales (Carnarvon and Merioneth) ...		
Isle of Man		
	42,500,000	75,000,000

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Mesozoic Ores.

	Reserves more or less developed. Tons.	Probable additional Reserves. Tons.
Yorkshire (Cleveland), Main Seam	190,000,000	150,000,000
Do. Pecten Seam ...	—	40,000,000
Do. Two-foot Seam ...	—	50,000,000
Do. Avicula Seam ..	—	10,000,000
Do. Top Seam	—	1,000,000
Lincolnshire, Frodingham Bed	162,000,000	336,000,000[2]
Do. Marlstone	36,000,000	—
Do. Northampton Bed	51,000,000[1]	360,000,000[2]
Do. Claxby Bed	—	4,500,000
Leicestershire, Marlstone	62,000,000	—
Rutland, Northampton Bed	86,000,000	—
Northants. and Hunts., Northampton Bed	1,115,000,000[1]	616,000,000[2]
Oxfordshire and Warwickshire, Marlstone	37,000,000	386,000,000
Wiltshire (Seend), Lower Greensand ...	—	5,500,000
Do. (Westbury), Corallian	26,000,000	22,500,000
Dorset (Abbotsbury), Corallian	—	11,500,000
Kent (Dover), Corallian	—	100,000,000
Inverness-shire (Raasay), Upper Lias ...	10,052,160	11,886,000
	1,775,052,160	2,104,886,000

Clay-Ironstones and Blackbands from Carboniferous and Wealden Beds.

Northumberland (Redesdale)	—	1,500,000
Yorkshire	110,760,000	104,320,000
Derbyshire and part of Notts	566,560,000	13,440,000
Warwickshire	4,608,000	—
Staffordshire, North	364,417,000[3]	939,883,000
Do. South (with Worcestershire)	11,520,000	62,680,000
Shropshire	—	30,000,000
Flintshire and Denbighshire...	—	20,000,000
South Wales and Monmouthshire	upwards of	5,000,000,000
Sussex and Kent (Wealden Beds)[4] ...	—	—
Fife	407,000	962,000[5]
Midlothian	185,000	2,117,400[5]
Ayrshire...	7,150,000	55,000,000[5]
Central Coalfield of Scotland	30,000	18,573,200[5]
	1,065,637,000	6,248,475,600

[1] This represents an area over which workable stone is known to occur near the surface, but of which a small part only in Lincolnshire, and a somewhat larger part in Northamptonshire, has at present been taken up.

[2] This represents an area under which workable stone is known or may be reasonably inferred to occur, but requires mining.

[3] Blackband Ironstones.

[4] An important source of ore till 1828. The ore is far from exhausted, but is nowhere worked.

[5] In addition to the estimates given under the head "Probable additional Reserves," the following are regarded as Possible Additional Reserves:—

	Tons.
Fife	6,874,400
Midlothian	4,646,000
Ayrshire	69,140,000
Central Coalfield...	318,414,000
	399,074,400

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Summary.

	Reserves more or less developed. Tons.	Probable additional Reserves. Tons.
Hematites, etc.	42,500,000	75,000,000
Mesozoic Ores	1,775,052,160	2,104,886,000
Clay-ironstones and Blackbands	1,065,637,000	6,248,475,600
	2,883,189,160	8,428,361,600

Grand total of all ores for Great Britain, 11,311,550,760 tons.

II.—FIELD WORK.

In the following summary the results of the field-work on iron-ores are referred to only so far as to show the methods by which the estimates given in the Table on pp. 6-7 have been obtained.

(1). Hematites, Etc.

CUMBERLAND AND LANCASHIRE.

From notes by B. Smith.

The output for this district was in 1915 1,656,484 tons, of which 333,086 tons were raised in the Furness district of Lancashire.

The reserve regarded as proved may be estimated at:—

Cumberland ...	Lamplugh-Beckermet district Millom district	30,000,000 to 40,000,000
Lancashire ...	Furness district...	3,500,000 to 4,000,000

or approximately 40,000,000 tons in all.

As regards further reserves in unproved ground, estimates are difficult partly in consequence of the sporadic occurrence of the ore-bodies, and partly because the Carboniferous Limestone, in which most of them occur, is covered by glacial deposits, or by red sandstone and breccia that may attain a thickness of 1,000 ft. or more. To prove such areas a systematic exploration by boring is essential.

One of the largest reserves for future exploration may occur in the unproved tract of New Red Sandstone which extends southwards from Egremont. Between Ullcoats and Winscales the existence of 20,000,000 to 30,000,000 tons has been proved by recent explorations, at depths ranging from 700 to 1,000 ft. The eastern limit of the productive area is likely to continue through Hale and Ponsonby Hall, and the western limit, along the valley of the Eden to St. John Beckermet and thence by Yottenfews. Farther south the Carboniferous Limestone may not be present or, if present, is likely to lie at a great depth. A borehole at Seascale, 2½ miles south of Yottenfews, failed to bottom the New Red Sandstone at 3,200 ft.[1] The area defined above contains approximately 5 square miles, and provided that the limestone underlies it and is productive in the same proportion as the ore-field already worked, it may contain a reserve of 40,000,000 to

[1] 'Summary of Progress for 1909,' *Mem. Geol. Survey*, 1910, p. 53, and J. W. Gregory, *Geol. Mag.* for 1915, p. 146.

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50,000,000 tons, in addition to the reserve mentioned above as having been proved.

Another possible reserve extends for about 1½ miles N.W. of the Helder Pit, Egremont. Neither the existence nor the accessibility of the reserve have yet been ascertained, and no allowance is made for it in the estimate.

In the Millom district ore may be assumed to occur as freely in the Carboniferous Limestone below the Duddon estuary as in Furness generally. On this assumption a reserve of 24,000,000 tons is estimated for the unexplored area lying between Hodbarrow and the mines situated east of the Duddon.

Minor reserves of ore, difficult of access, occur in the Eskdale granite, Skiddaw slate, and in the rocks of the Sca Fell group.

In the Furness district some reserves probably exist in the deeper parts of veins which were abandoned through water trouble, but the largest deposits are likely to be found near the Duddon estuary and in the Dalton-Ulverston region. Prospects are less good south-eastwards towards the western shore of Morecambe Bay. Apart from any ores to be found in the deeper parts of the veins, the estimates for Furness amount to about 12,000,000 tons and are included in the 24,000,000 tons estimated for the Duddon estuary.

The composition of the Cumberland hematite is shown by the following analyses:—

	Blast Furnace Ore average from 15 mines (not including Hodbarrow).	Hodbarrow Ore average.
	Per cent.	Per cent.
Metallic iron	51·57	57 to 58
Insoluble residue	11·90	3·5
Phosphorus	·0077	·006
Calcium carbonate	3·02	
Moisture	4·26	6·0

The Furness ore is similar in composition. The ore of the Nigel Pit, Roanhead Mine, is almost as rich in metallic iron as that of Hodbarrow, but the insoluble residue is larger, silica ranging up to 14 per cent.

DURHAM (WEARDALE).

From notes by R. L. Sherlock.

The ores occur in the Yoredale Beds in connection with fissures which develop a breadth of several feet in some of the limestones, but may be represented by a mere film in the intervening shales. They are described as brown hematites, and according to an analysis furnished by the Weardale Steel, Coal and Coke Co., Ltd., yield, after drying, 40·8 per cent. metallic iron with about 9 per cent. of silica. The percentage of metallic iron has increased in the ore worked in late years. In depth the ores are spathic.

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GLOUCESTERSHIRE (FOREST OF DEAN).

From notes by Prof. T. F. Sibly.

The ores are exclusively hematites.[1] The chief deposits lie in the upper beds of the Carboniferous Limestone Series, which crop all round the coal-basin except over a distance of about 3 miles on the northern margin and an equal distance on the south-eastern margin. Workings extending over many centuries have proved considerable deposits all along the eastern crop, and as far north as Staunton on the western crop. Only a few tracts, on the western margin between Lydney and Staunton, and on the north-eastern margin at Wigpool Common, are in process of development at the present time.

Two and a half million tons is a conservative estimate of the workable reserves of ore in the proved areas.

The unproved areas lie in the deep, and estimates of reserves within them would involve assumptions as to how far the deposits persist in depth.

The ores vary greatly in iron content, and appear to vary considerably in silica content, but are always low in phosphorus and sulphur. The following analysis, quoted by permission from a report by the Deputy Gaveller of the Forest of Dean, may be regarded as giving good average values for iron, sulphur and phosphorus, but is unusually high in silica and low in lime and magnesia:—

Average sample of ore as received from Westbury Brook (Edge Hill) Mine in 1884.

	Per cent.
Peroxide of iron	50·0
Alumina	3·71
Manganese oxide	·04
Calcium carbonate	3·79
Magnesium carbonate	·88
Silica	19·25
Sulphuric acid	·02
Phosphoric acid	·06
Combined water...	8·20
Moisture	13·50
	99·46
Iron	35·0
Sulphur	·01
Phosphorus	·03

SOUTH WALES (LLANHARRY DISTRICT).

From notes by Prof. T. F. Sibly.

Considerable deposits of hematite, similar to that of the Forest of Dean, have been proved, or may reasonably be believed to exist, in a tract on the 'South Crop' of the Carboniferous Limestone which extends east and west between the Rivers Taff and Ewenny, north-west of Cardiff.

In the eastern part of this tract, lying between the Taff at Taff's Well on the east, and the Ely at Pont-y-Clun on the

[1] That is, in the commercial sense. The ores consist chiefly of hydrated ferric oxide; true hematite in the massive form rare.

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west, two or three million tons of ore were raised during the latter half of the 19th century. The reserves of ore in the unproved portions of this area are probably small.

In the western part of the tract, a strip of country about 4 miles long and $\frac{1}{5}$ to $\frac{1}{4}$ mile wide between the Ely on the east and the Ewenny on the west, a small area is in process of development at the Llanharry Mine. The total reserves of ore (*a*) in process of development at Llanharry Mine, and (*b*) existing in ground to the west of that mine not yet proved, should not be less than four or five million tons.

The following is a *typical analysis* of the ore from the Llanharry Mine, communicated by the Cardiff Hematite Iron Ore Company:—

Analysis of Llanharry Hematite Iron Ore.

By R. W. and A. J. Atkinson, July 15th, 1912.

Sampled jointly by Messrs. Atkinson and G. R. Thompson.
Eight samples in June, 1912, compounded, giving the following results:—

	In sample dried at 212° F.		
In HCl. solution.	Per cent.		Per cent.
Peroxide of iron	79·41	Metallic iron	55·59
Protoxide of manganese	0·07		
Alumina	0·221		
Lime	3·20		
Magnesia	0·19		
Sulphur	0·014		
Phosphoric acid	0·025	Phosphorus	0·011
Combined water	7·80		
Carbonic acid	2·50		
Insoluble in HCl.			
Silica	5·87		
Alumina	0·44		
Lime	0·26		
Titanium	absent		
	100·00		

Moisture, 7·30 per cent. Iron (raw), 51·53 per cent. Mechanical condition, 25 per cent. lump, 25 per cent. rubble, 50 per cent. small (not fine).

CORNWALL AND DEVON.

From notes by H. Dewey.

Hematites, carbonates, magnetite and pyrites occur in the outer fringes of the tin and copper mining regions. The principal iron-mines are situated near the St. Austell granite in Cornwall and on the eastern edge of the Dartmoor granite in Devon. Several minor lodes have been worked near Bodmin and St. Austell.

In Cornwall the Perran Iron Lode can be traced for upwards of 8 miles, with a width ranging up to 50 ft. It contains in places much breccia, mostly of quartz. The following mines upon the lode are taken in order from the coast eastwards:—Gravel Hill (Penhale Iron Mine), Halwyn, Mount and Trebisken, Treamble, Great Retallack, Duchy Peru, Deer Park and Penhallow Moor.

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Considerable lengths of untouched lode intervene between these mines, but it must not be assumed that they will be continuously and equally productive. At the Duchy Peru Mine, where breccia was greatly developed, the lode died out both in depth and laterally.

Masses of iron ore, several fathoms thick, were found at the intersection of the lode with north-and-south lead- and zinc-lodes. As a rule about half the contents of the lode were iron ore. The ore occurs as carbonate, but changes near the surface into brown hematite or limonite.

In the brown hematite of the Treamble Mine, according to various analyses, the metallic iron varied from 55·7 to 60 per cent., phosphoric acid from a trace to ·86, manganese oxide up to ·8, silica from 1·2 up to 5 per cent. In the carbonate ore the loss by calcination was 32·8, the metallic iron 54·30, and metallic manganese 8·10 per cent. Phosphoric acid occurred in traces only, and it is believed that its presence in the brown hematite is due to its having been introduced by surface-water.

North of Lostwithiel a series of large open workings extends for half a mile. The ore consisted of brown and red hematite (reputed to contain 44 per cent. metallic iron), and the total yield up to 1883 was 121,796 tons. It is doubtful whether much ore remains above the 12-fathom level, that is—the first level below adit. In places the mine is 400 ft. deep.

Near Bodmin several minor lodes difficult of access have yielded hematite. The reserves appear to be small.

In Devon magnetite, specular iron ore and brown hematite occur.

At Hay Tor Mine there are, according to an old plan, three beds of magnetite, 8 ft., 13 ft., and 5 ft. thick, but the three beds now being worked near the surface measure 1½ ft., 2 ft., and 3½ ft. respectively. Hematite has been worked opencast along the lode for nearly a mile, and the weathered ore shows included lumps of magnetite. The old adit is being reopened and new shafts are being sunk. The present output of 60 to 70 tons a month is likely to be increased.

The percentage of iron in the magnetite ranges between 40 and 70.[1]

In the Sharkham Mine, near Brixham, hematite occurs in pockets in Devonian Limestone.

Many pockets have been worked out, but the area is not exhausted. The ore is graded into 'firsts,' containing 60 per cent. of iron, and 'seconds,' with 30 per cent. Silica ranges up to 20 per cent. Sulphur, phosphorus and manganese are low.

Specular Iron Ore, known as 'Shining Ore' or 'Devonshire Sand,' occurs in narrow veins in the granite of eastern Dartmoor. It is being still dug at the Kelly Mine, Lustleigh, and the Great Rock Mine, Hennock. The ore is used for making paint and other purposes.

[1] 'The Geology of Dartmoor,' *Mem. Geol. Surv.*, 1912, pp. 79, 80.

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SOMERSET.

From notes by T. C. Cantrill and R. L. Sherlock.

In the Brendon Hills the ore occurs in pockets on veins in Devonian rocks. The pockets may be close together or as much as a mile apart, and may reach a length of 600 yds. along the vein with a width up to 30 ft., and a depth proved to reach 1,000 ft. The veins agree in direction with the strike of the rocks and dip southwards at 45° to 65°. 'Brown hematite,' 'black ore' (hematite with psilomelane), 'potty ore' (cellular hematite), 'red ore' (spathose ore with hematite) and 'white ore' (poor spathose ore) were raised. The ore yielded spiegeleisen of good quality containing about 20 per cent. of manganese. (J. A. Phillips, 'A Treatise on Ore Deposits,' Ed. 2, 1890). An estimate was made in 1868 by Mr. Morgan Morgans, who had been connected with the mines for nine years, that there existed a reserve of 12,000,000 tons within 300 fathoms of the surface.[1] Since then only 444,000 tons have been raised, and the mines are now abandoned. The estimate, therefore, appears to have been too optimistic, and the reserves must be regarded as doubtful.

On Exmoor the mode of occurrence appears to have been the same as at Brendon Hills. Veins have been worked at various places, but their continuity remains to be proved. They may be continuous with those of Brendon Hills.

Analyses of the Brendon and Exmoor ores are given in the *Quart. Journ. Geol. Soc.*, vol. xv, 1859, p. 105.

NORTH WALES (CARNARVONSHIRE, MERIONETH AND ANGLESEY).

From Notes by T. C. Cantrill and R. L. Sherlock.

In Carnarvonshire, Merioneth and Anglesey, pisolitic iron ores, interbedded in Ordovician shales, have been worked at widely separated localities. Though not continuous, ore-beds are certainly more extensive than has yet been proved, but to trace their outcrop and to determine the variations in their characters would require a detailed survey of the stratigraphy of the whole district. The thickness of one of the beds worked has been found to range up to 23 ft., and in one case the ore is associated with a bed of manganese ore 3 ft. thick. These pisolitic ores of North Wales have so far not found favour with the ironmasters. An analysis of the ore from Bettws Garmon, made when the best quality was being got, shows 40 per cent. of metallic iron and 1·62 of phosphorus in the dried ore. The ore now being worked shows 30 per cent. of iron.

Hematite has been worked in the Carboniferous Limestone, but on a small scale and apparently to exhaustion. At Nantuchaf it was raised in connection with manganese. All the mines are inactive, but proposals to test the ground between Cwm and Dyserth Station by an adit are under consideration. The reserves, if any exist, from these hematites are not included in the estimates for North Wales.

[1] *Trans. S. Wales Inst. Eng.*, vol. vi, 1870.

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ISLE OF MAN.

From notes by G. W. Lamplugh, F.R.S.

Veins carrying hematite and some spathose ore occur in the Manx Slates (Cambrian?) in the north-eastern part of the Isle of Man and have been mined, particularly between the years 1854 and 1881, when they yielded in the aggregate 12,896 tons of hematite. The ore occurred in detached bunches, and the mining was never profitable. Such reserves as may exist cannot be estimated at more than a few thousand tons.

In the northern part of the island an area of Carboniferous Limestone, of unknown extent, is buried deeply under Glacial deposits. The conditions of this limestone resemble those of the hematite-bearing limestones of Cumberland. The possibility of hematite occurring in this tract has been frequently discussed, but has been hitherto regarded as too speculative to be tested practically by borings.

(2) Mesozoic Ores.

YORKSHIRE (THE CLEVELAND DISTRICT).

From notes by G. W. Lamplugh, F.R.S.

The seams of ironstone recognised in the Cleveland District occur in the Lower Oolite and the Middle Lias.

Table of seams.

	Thickness. Ft.
Top or Oolite Seam	impersistent; 4 ft. to 7 ft. in present workings.
Strata (Upper Lias)	240
Main Seam	6 to 11
Strata	2 to 5
Pecten Seam	1½ to 6
Strata	3 to 6
Two-foot Seam	1½ to 2½
Strata	20 to 30
Avicula Seam	0 to 3

Practically the whole of the working is done by deep mining, partly by day-levels and partly by shafts ranging up to about 700 ft. in depth. The workings are at present nearly all confined to the Main Seam.

The Top Seam is extremely variable in composition and thickness. At present only two patches are being worked, and the reserves in these probably do not exceed one or two millions of tons of ore averaging 30 per cent. of iron. Two rich pockets of magnetic ironstone were found in this bed in Rosedale about 70 years ago, but borings have as yet failed to disclose further masses of this kind.

The Main Seam occurs at the surface in the northern part of the district but dips southwards underground. In the north-western part, now practically exhausted, the seam was 9 to 11 ft. thick, consisting of good ore throughout, and in the raw state containing 30 to 35 per cent. of iron. Southwards it deteriorates and is split by a parting of shale. Where the shale first sets in there is usually about 4 ft. of good stone above and about 3 ft.

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below it. Most of the present mines are working across this belt, which contains large reserves of ore averaging in the raw 30 per cent. of iron. Still farther southwards the shale has thickened to 2 ft. and the workable ore has diminished to 5 ft. or less with an average iron-content of 27 per cent. The royalties at present being worked cover the area to which all the above remarks refer, and contain a reserve estimated at 190 millions of tons.

Farther south the seam continues to deteriorate and within 2 or 3 miles becomes worthless, being broken up into strings and bands of nodules in shale. The intervening ground contains a quantity of ore which may be worth extracting under favourable economic conditions, and may be estimated at 150 millions of tons.

The Pecten and Two-foot Seams have been worked in small quantities in conjunction with the Main Seam in the northern area. The Pecten and Avicula Seams have also been worked independently at Grosmont and other places in the Esk valley where the Main Seam is not developed. The Pecten Seam yields ore of low quality and is in places too much mixed with shale to be of value. The Two-foot Seam is fairly constant and of medium quality in the northern and western part of the district, but splits up and deteriorates in the southern part.

The Avicula Seam is fairly persistent, but shaly and lean. Locally in the Esk Valley it improves, and has yielded at Grosmont 7,500 to 8,000 tons per acre, averaging about 25 per cent. iron in the raw stone.

LINCOLNSHIRE, LEICESTERSHIRE, RUTLAND AND NORTHAMPTONSHIRE (WITH HUNTS).

From notes by C. B. Wedd.

Three ore-beds are in use in various parts of these counties. The Northampton Bed forming the basal part of the Interior Oolite is worked in Lincolnshire, Rutland and Northamptonshire; the Marlstone Bed of the Middle Lias is worked in Leicestershire and Lincolnshire; the Frodingham Bed of the Lower Lias is worked in Lincolnshire. All are quarried in open workings, except a small but increasing proportion of the Northampton Bed which is mined at shallow depths. Besides these the Claxby Bed of Lower Cretaceous age has been worked in Lincolnshire, but has been rejected of late years. It contains about 30 per cent. of iron and is of siliceous and slightly calcareous nature. The estimate of reserves of the Claxby Bed is based on the supposition that 3 ft. of ore would be available over an area of one square mile. The actual thickness and extent are considerably greater.

The estimates of ironstone reserves set forth in the table are based on present-day requirements, without reference to the possibility of utilising lower grade ore at some future date.

The Frodingham Bed is a calcareous ore with about 1 per cent. manganese and ·3 of phosphorus. The dried stone contains 20 to 25 per cent. of iron. The cover removed in working it ranges

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from nil to upwards of 60 ft., and the removal of 100 ft. is contemplated before resorting to mining.

The Marlstone Bed is partly siliceous, partly calcareous with about ·3 to ·4 per cent. of manganese, and ·3 of phosphorus. The dried stone contains 32 per cent. of iron, and the cover removed ranges up to 15 ft. in thickness. Under a greater thickness of cover the Marlstone of the Midlands becomes too calcareous to be worked as an ironstone.

The Northampton Bed is siliceous, with ·1 to ·3 per cent. of manganese and ·3 to ·7 of phosphorus. The dried stone averages about 38 per cent. of iron, and the cover removed ranges up to 40 ft. in thickness.

The large reserves estimated for the Northampton Bed lie mainly in Northamptonshire. The area occupied by this ironstone may be divided into:—

(*a*) A central district lying between Rockingham, Desborough, Wollaston, Thrapston, Brigstock and Dene. The ore may be assumed to be generally of workable quality, wherever it has survived denudation.

(*b*) A district extending south-westward of (*a*) at least as far as Towcester.

(*c*) A district extending northward to the northern boundary of the county. In (*b*) and (*c*) the ore has not been proved to keep its quality throughout, and only those parts in which it is known to do so are taken into account. A further district, also, lying eastward and south-eastward of the Nene Valley, where the ironstone finally passes under cover, is as yet untried. The reserves may be great, but are not included in the estimates.

NORTHAMPTONSHIRE (*Contd.*), OXFORDSHIRE AND WARWICKSHIRE.

From notes by J. Pringle.

In Northamptonshire the Marlstone Bed occupies an area lying between Daventry and Bugbrook and extending southwards, but little is known of its quality further than that it contains 23 per cent. of iron at Kings Sutton, but is likely to vary greatly. It is being opened up at Hellidon and Byfield.

In the districts lying to the north, south and west of Banbury (Oxfordshire and Warwickshire) the Marlstone has a wide outcrop and in its upper part is generally ferruginous, but the percentage of iron is known to vary widely in different parts of the area. Owing to cost of transport and other practical difficulties the field has not yet been fully developed, though the bed has been worked on a limited scale for many years and several new workings are being commenced. Until development is further advanced, it is not possible to say how much of the field will pay for exploitation. The estimate of reserves includes exposed tracts, and all the ground in which the cover does not exceed 10 ft. in thickness.

The ore is mainly calcareous but locally siliceous, and the iron-content, where known, varies from about 20 to 30 per cent., or to a little more than 30 per cent. in the richer parts at Hook Norton and Adderbury.

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WILTSHIRE.

From notes by J. Pringle.

At Seend the iron-ore occurs in an outlier of Lower Greensand and covers an area of 179 acres, of which about 64 acres is occupied by the village. The average thickness is taken as 20 ft. and the yield 2,500 tons per foot per acre. The silica percentage is upwards of 27, and that of iron about 37. The workings ceased in 1874.

At Westbury the ore occurs in the top beds of the Corallian. At the outcrop it weathers reddish-brown, but under cover it is bluish-green and known as 'blue ore.' The crop-workings are nearly exhausted, but borings through the cover of Gault or Kimmeridge Clay have proved the existence of the ore over an area of nearly 1,500 acres. The average thickness is 11 ft. The phosphorus-content is about ·5 per cent., and metallic iron is about 30 in the raw ore, and 42·5 in the calcined ore. The 'blue ore' loses about 30 per cent. on calcination. The insoluble silica ranges from about 11 in the 'blue ore' to about 16 per cent. in the 'brown ore,' according to the few analyses available.

DORSET.

From notes by J. Pringle.

The ore occurs in the uppermost beds of the Corallian, and has resulted from the local alteration of a calcareous grit. It averages about 20 ft. in thickness and covers an area of about 256 acres, 60 of which are occupied by the village of Abbotsbury. The extension of the ore under the Kimmeridge Clay has not been proved, and the possible reserves thus covered are not included in the estimate. The only analysis available gives a silica-content of 42·6, and of peroxide of iron 43·97 per cent., equivalent to about 34 to 35 per cent. of iron in the roasted ore.

KENT.

From notes by G. W. Lamplugh, F.R.S.

In boring and sinking operations for coal in Kent, ferruginous deposits have been proved in the overlying Jurassic rocks, one of which occurs in the Upper Corallian formation in about the same stratigraphical position as the iron ore of Westbury, Wilts, and is of similar character. The ore is made up of brown oolitic granules embedded in a marly matrix. The iron-bearing quality of the rock depends upon the relative abundance of the granules, which varies from place to place. The best and thickest ore was found in the Dover Colliery shafts, where the bed is about 16 ft. thick and is stated to contain over 32 per cent. of iron in the raw stone. It is known to diminish in thickness and value in the interior country until it becomes worthless, but the borings have proved a workable area around Dover estimated to be about six square miles and to contain approximately 100 million tons of available ore after allowing for permanent pillars, etc.

The percentage of metallic iron in a specimen from one of the borings has been given at 32·2, that of silica 13·77, phosphorus ·4 per cent. The loss on calcination was 19·4 per cent.

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INVERNESS-SHIRE (RAASAY).

From notes by G. W. Lee.

The Raasay ore is composed of ooliths of silicate of iron embedded in limestone, and occurs as a bed in the Upper Lias. The bed ranges up to 17 ft. in thickness, being at its maximum in the southern side of the field, and gradually thinning out northwards on the eastern side of the island.

The area regarded as proved covers 370 acres with a calculated yield of 27,168 tons per acre.

A large area concealed by Oolitic formations and granophyre, as yet wholly unproved, exists in the middle and western part of the island, north of the proved area. For this a "probable reserve" of 5,094,000 tons is estimated on a basis of 300 acres at 16,980 tons per acre, but no further "possible reserves" can be safely assumed. Under the Oolitic formations of Beinn na' Leac a "probable reserve" of 6,792,000 tons is estimated, on a basis of 250 acres at 27,168 tons per acre.

Analyses show:—Metallic iron in raw ore, 25·2 (calcined 35·7); silica, 6·5; alumina, 5·6; lime, 17·6; carbon dioxide, 28·3; phosphoric acid, 2·3; sulphur, 0·2 per cent.

(3) CLAY-IRONSTONES AND BLACK BANDS FROM THE CARBONIFEROUS AND WEALDEN BEDS.

IRONSTONES OF THE COAL MEASURES.

From notes by W. Gibson.

The coalfields of Yorkshire, Derbyshire, Warwickshire, Worcestershire, Staffordshire, Shropshire and South Wales contain great reserves of ironstone. These, however, occur as nodules, cakes, and thin bands generally from 1 to 3 in. in thickness, lying separately in shales from 6 to 80 ft. thick, the aggregate thickness of ironstone seldom exceeding 1 ft. Only in North Staffordshire, where the beds of ironstone range from 1 to 6 ft. in thickness, is it, at present, found profitable to mine the ironstones apart from their closely associated coals. Here are found mines whose operations are confined to raising ironstone; in the other areas ironstone is got occasionally, but only in the proportion of about 1 ton to 160 of the associated coals.

Typical analyses of the Black Bands and Semi-Black Bands of the proved area in North Staffordshire can be selected from numerous examples. As regards Shropshire, South Staffordshire, Yorkshire, Derbyshire and South Wales, the analyses given in 'The Iron Ores of Great Britain,' *Mem. Geol. Survey*, 1856-58, were made from samples obtained when the ironstones were extensively worked. They should therefore represent the average composition more truly than would specimens from the particular districts to which the limited workings of the present day are confined.

The reserves of ore can be estimated with considerable accuracy in North Staffordshire, but in the majority of coalfields the necessary data are wanting. This applies to the yield per acre, and to the area over which any particular bed may extend. The old

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workings were situated where the yield was profitable and only such records as were made in sinking shafts exist for other sites. Again, in raising ironstones from coal-mines the stone is only obtained during some process necessitating its removal to the surface. The yield therefore may be above or below the average. Further, many of the ironstones are capricious in their occurrence. Estimates for the unproved areas are therefore only given for such beds as are known to be fairly constant over the proved areas.

In all cases, probably as much as 10 per cent. should be deducted from the estimates to give the amount of ore it would be possible to get at a profit in working the associated coals exclusive of losses due to faults, barriers and other causes.

Abundant as are the ironstones of the Coal Measures of the counties named in the Table on p. 7, they would not replace the equally rich, more easily wrought and cheaply got Mesozoic ores even under favourable conditions as regards proximity to existing furnaces. The comparatively small quantities of clay-ironstones, other than black bands, at present raised from the Coal Measures are almost exclusively used in the production of high-priced pig-iron.

YORKSHIRE.

From notes by W. Gibson.

The Low Moor Ironstone has been regarded as a source of an exceptional quality of iron, a reputation gained partly through the care exercised in cleaning it and the purity of the coal used for smelting it. It is developed in the neighbourhood of the northern part of the coalfield, between Leeds and Bradford, and occurs as 3 to 10 in. of ore in about 30 in. of shale. The percentage of iron averages about 29..

The Clay Wood and White Mine Ironstone occurs in the neighbourhood of Sheffield as 3 courses in 6 to 10 ft. of shale. Metallic iron averages about 31 per cent. The Tankersley Ironstone is developed between Barnsley and Sheffield, and consists of 12 to 15 in. of ore in 6 ft. of shale. Metallic iron ranges from 16 to 27 per cent.

	Yield per acre. Tons.	Developed area. Tons.	Additional reserve. Tons.
Low Moor Ironstone	1,000	3,840,000	38,400,000
Clay Wood and White Mine Ironstone	1,500	53,760,000	40,320,000
Tankersley Ironstone	2,000	35,840,000	25,600,000
Ironstone of restricted occurrence ...	—	17,320,000	—
		110,760,000	104,320,000
		215,080,000	

DERBYSHIRE AND PARTS OF NOTTS.

From notes by W. Gibson.

The Dale Moor Rake and Civilly Rake are developed near the southern margin of the coalfield and contain 27 to 33 per cent. of metallic iron.

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The Honeycroft Rake Ironstone covers a considerable area near Dale, in the same neighbourhood. It contains 32 per cent. of metallic iron. The additional reserve is possibly large but unproved.

The Brown Rake Ironstone, with 18 to 30 per cent. of metallic iron, has a wide extension along the western margin of the coalfield. Here there is probably a large additional unproved reserve.

	Yield per acre. Tons.	Developed area. Tons.	Additional reserve. Tons.
Dale Moor and Civilly Rakes	3,500	8,960,000	13,440,000
Honeycroft Rake Ironstone	6,000	38,400,000	unproved.
Black Shale and Striped Rakes ...	4,000	304,000,000	„
Brown Rake	2,500	115,200,000	„
Ironstones of restricted occurrence ...		100,000,000	„
		566,560,000	13,440,000
		580,000,000	

WARWICKSHIRE.

From notes by W. Gibson.

The White Ironstone, with an average iron-content of 33 per cent. in the raw stone, is estimated to contain 800 tons per acre over an area of 9 square miles, or 4,608,000 tons. Other ironstones, such as the Gubbin, the Black Ironstone and Blue Flats, are capricious in occurrence. The value of the ironstones in the proved extension of the coalfield west of Coventry is not known. They lie at a considerable depth.

NORTH STAFFORDSHIRE.

From notes by H. Dewey.

This is the only coalfield in England in which ironstone is now being extensively raised. It is especially rich in iron ores, still largely used in the manufacture of pig-iron and steel, but not to the extent the great capabilities of the coalfield would lead one to expect. The output decreased from 1,783,000 tons in 1884 to 776,362 tons in 1902 but has since risen.

The ironstones fall naturally into two classes occupying a constant position in the Coal Measure sequence. Those in the Blackband sub-division are laminated ores of the variety known as Blackbands; those below are classed as Clay-ironstones.[1]

Four Blackband ironstones have long been worked in North Staffordshire. The Halfyard, Red Shagg and Red Mine Ironstones are developed towards the central part of the coalfield, but in the southern part the Bassey Mine alone exists. Towards the western margin the ironstones pass into limestones. Some of the estimates made by various authorities appear to have been made on the assumption that the whole coalfield, with an area of 100 square miles, would be productive of ironstone.

[1] 'The Geology of the North Staffordshire Coalfields,' *Mem. Geol. Surv.*, 1905, p. 213.

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The *Halfyard or Blackband Ironstone* is worked on a small scale and mixed with the other 'Red Mines' before calcination. It is said to average 37 per cent. metallic iron, phosphorus ·3, sulphates and sulphides 2·0.

The *Red Shagg Ironstone* contains on the average 38·8 per cent. metallic iron, ·4 phosphorus, sulphates and sulphides 2·5. Productive area, 18 square miles.

The *Red Mine Ironstone* is richer in the lower than in the upper part. The averages of the two parts, according to a large number of recent analyses, show: metallic iron, 39·4 to 26·8; phosphorus, ·19 to ·28; sulphur, trace to nil; manganese, 1·23 to·7. Productive area, 18 square miles.

The *Bassey Mine* is the principal ironstone now worked. In the calcined ore the iron-content ranges from 49·5 to 54·5, phosphorus from ·5 to ·7, sulphur up to ·95. Productive area, 28¼ square miles.

The *Burnwood* is a semi-blackband, which passes into a clay-ironstone. In the raw stone the iron-content ranges from 24·9 per cent. in the Central District to 37·79 in the south. Of the clay-ironstones only two bands of irregular occurrence are now being worked, namely the *Cannel Row*, with 57·9 metallic iron, ·83 phosphorus, 1·17 sulphur, 1·83 manganese, in the calcined ore; and the *Pennystone* with 47·85 metallic iron, ·5 phosphorus, ·54 sulphur, in the calcined ore. Productive area of the clay-ironstones, 51 square miles.

In the Cheadle Coalfield the Froghall Ironstone lies near the base of the Coal Measures. It was highly valued for its kindly properties in the smelting furnace, and was so exhaustively mined that except for some patches now being used for making red paint it has been practically worked out. It was deposited in the form of a thin lenticle, under strictly localised conditions. The limits of the lenticle as a workable ironstone appear to have been located on all sides by borings, and such reserves as exist are negligible.

SOUTH STAFFORDSHIRE (WITH WORCESTERSHIRE).

From notes by W. Gibson.

To the south of the Bentley Faults, in an area where the coal and ironstones have been extensively worked, ironstones occur as nodules, cakes or thin bands from 2 to 9 in. thick, and are situated on several horizons from near the base of the Coal Measures to just above the Brooch Coal. Analyses of the ironstones are given in the 'Iron Ores of Great Britain,' *Mem. Geol. Surv.* 1856, pp. 131-164. The lowest ironstones are exhausted and the others have been extensively worked. At the present time the White Ironstone below and the Gubbin Ironstone above the Heathen Coal are the principal stones raised in getting this coal. Small quantities are obtained with the Brooch and the Thick Coal. The output from individual mines is small, not exceeding 200 tons per week.

Within the visible coalfield the bulk of the ironstone has been obtained. About 6,000,000 tons of reserve of Gubbin Ironstone occur in the Rowley Regis District, and some remains to the west

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and east of Dudley and about Netherton. In the concealed coalfield the White Ironstone on the west and the Gubbin Ironstone in the east practically remain untouched.

The Gubbin and Brooch Ironstones are estimated to contain 7,680,000 tons in a developed area of 4 square miles, and the same amount in an undeveloped area of 4 square miles, the yield in both cases being taken as 3,000 tons per acre. The White Ironstone, with a yield of 300 tons per acre on an area of 2 square miles is credited with 3,840,000 tons, making totals of reserves 11,520,000 tons, additional reserves 7,680,000 tons, or 19,200,000 tons in all.

To the north of the Bentley Faults the reserve is estimated at 55,000,000 tons, but ironstones are raised in small quantities and only in conjunction with coal.

SHROPSHIRE.

From notes by H. Dewey.

The iron ores of Shropshire were worked extensively when the furnaces in Coalbrookdale were in operation, but the output now is less than 4,000 tons a year. The ores occur as nodules embedded in shales in the lower part of the Coal Measures, and are better developed in the northern than in the southern part of the coalfield. The principal mines now working ironstone belong to the Lilleshall Company, but the stone is got only in driving roads for coal.

The bands from which ore is raised are:—

The Ragged Robin, the band now principally worked, underlies the Fungous Coal, and is irregular. Metallic iron 32 per cent. after calcination.

The Blackstone used to be highly valued for making 'best best' cold-blast pig-iron. Metallic iron about 38 per cent.[1]

The Yellowstone contains about 30 per cent. metallic iron after calcination.

The Blue Flats and White Flats contain about 36·4 per cent. and about 35·6 per cent. respectively of metallic iron.[1] The White Flats now being worked yield 30 per cent. of iron after calcination.

The Pennystone, which is regarded as the most suitable for cold-blast pig-iron, contains 30-35 per cent. of iron after calcination.

It is estimated that there are 14,000,000 tons of ungotten ore in the northern third of the coalfield. If a similar yield obtains over the whole field the reserves would be about 42,000,000 tons, but a large part is exhausted and most of the area partially worked out. It may be assumed that not less than 30,000,000 tons remain.

FLINTSHIRE AND DENBIGHSHIRE.

From notes by T. C. Cantrill.

These ironstones occur as nodules averaging about 3½ inches in thickness. The more important bands overlie the Llwyneinion

[1] 'Iron Ores of Great Britain,' *Mem. Geol. Surv.*, part 4, 1862.

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Half-Yard, the Wall-and-Bench, and the Ruabon or Lower Yard coals, the first-named being regarded as the best.

The smelting of the local ironstones was carried on mainly at Mostyn, Brymbo, Acrefair near Ruabon, and Ponkey near Rhôsllanerchrugog. The working of ironstone as a separate industry has long been extinct. In 1911 341 tons of ironstone were raised from coal mines in Denbighshire, but in 1915 none was obtained from either Flintshire or Denbighshire. The iron-content is said to have ranged from 20 to 30 per cent.

The estimate of reserves has been made on the assumption that the principal courses of clay-ironstone are available over an area of 10 square miles.

SOUTH WALES AND MONMOUTHSHIRE.

From notes by Prof. T. F. Sibly.

The clay-ironstones of the Lower Coal Series, formerly worked on a large scale, are nowhere mined systematically at the present time. Small quantities (the total output was 15,763 tons in 1915) are raised incidentally at a few collieries in Monmouthshire and East Glamorgan. The nodules or 'balls' of ironstone are brought down, mixed with shale, in ripping the roofs of coal-seams to make the roadways, and in some cases the ironstone is recovered from the rubbish. A little is used locally (at Ebbw Vale), but the bulk appears to be sent to South Staffordshire furnaces.

The ironstones, from Pembrokeshire to Monmouthshire, were analysed when they were being worked and the detailed results were published in 'The Iron Ores of Great Britain,' *Mem. Geol. Survey*, part 3, 1861. They appear to have contained about 34 or 35 per cent. of metallic iron on the average, but Blackbands of occasional occurrence ranged up to nearly 39 per cent. Judging from the specimens analysed, the ores worked in Pembrokeshire contained less iron than those worked in the main coalfield.

As regards reserves the number of courses that exist is so great, and the areas over which they may be productive are so difficult to define, that precise estimates are not possible. The reserves are undoubtedly great.

NORTHUMBERLAND (REDESDALE).

From notes by R. L. Sherlock.

The ironstone worked in Redesdale occurs as nodules embedded in about 30 ft. of shale in the Yoredale Beds, and is closely akin to the clay-ironstones of the Coal Measures. The iron-content appears to reach about 34·86 in a perfectly clean sample of the raw stone.

SUSSEX AND KENT (WEALDEN BEDS).

The working of these ores, which probably commenced in pre-Roman times, ceased in 1828. An account of them is given in 'The Geology of the Weald,' *Mem. Geol. Survey*, 1875, chap.

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xix., etc. No estimate of the amount that has been worked is possible.

FIFE.

From notes by G. W. Lee.

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Blackband in Coal Measures, Bogside	95 acres; 5,200 tons	—	494,000	—
(2) Blairhall or Upper Comrie Blackband	150 acres; 3,128 tons	—	468,000	—
(3) Do. do.	400 acres; 3,120 tons	—	—	1,248,000
(4) Lower Comrie Blackband ...	600 acres; 2,080 tons	—	—	1,872,000
	200 acres; 3,120 tons	—	—	
(5) Lochgelly Blackband ...	300 acres; 4,680 tons	—	—	2,402,400
	320 acres; 3,120 tons	—	—	
(6) Blackband below Six-foot Coal	200 acres; 4,420 tons	—	—	884,000
(7) Blackband in roof of Lochgelly Splint Coal	120 acres; 2,080 tons	249,600	—	—
(8) Blackband in roof of Mynheer Coal	47 acres; 1,740 tons	80,000	—	—
(9) Clay-band in roof of Five-foot Coal	129 acres; 600 tons	77,400	—	—
(10) Denhead Blackband in Lower Limestone Group	150 acres; 3,120 tons	—	—	468,000
		407,000	962,000	6,874,400

These ironstones are all in the Limestone Coal Group except the first and the last.

The output of ironstone in Fife was 2,128 tons in 1913, all from Coal Mines.

(1) Worked about 50 years ago with a coal, 2 ft. 2 in. thick, of which it forms the roof.

(2) Exhausted over the more accessible areas.

(3) Westward extension to depth of 200 fathoms. A few boreholes have reached the seam.

(4) Estimates founded on a few boreholes only.

(5) Chiefly near Lochgelly. The estimate includes 624,000 tons for the Cowdenheath district, where mining has just been commenced. Iron in calcined ore 34 to 56·8 per cent.; sulphur, 1·4; phosphorus, 3·9 per cent.

(6) Working from 1870–74. The ore dips to the S.E. and has not been proved.

(7) Small quantities are raised when occasion offers.

(8) Worked when the distance above the coal is not too great. Iron (raw ore), 33·59; manganese, 0·69; sulphur, 0·81; phosphorus, 0·82 per cent.

(9) Taken out with the coal; 600 tons raised in five months in 1917.

(10) Worked long ago at Denhead and Lumbo. Intervening ground not known.

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MIDLOTHIAN.

From notes by T. Robertson.

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Great Seam Blackband, Mauricewood	8½ acres; 7,106 tons	—	68,400	—
Do. do.	385 acres; 3,600 tons	—	—	1,410,000
(2) Loanhead No. 2 Blackband	13 acres; 7,281 tons	95,000	—	—
Do. do.	96 acres; 5,200 tons	—	500,000	—
Do. do.	44 acres; 5,200 tons	—	—	228,000
(3) Loanhead No. 1 Clayband and Blackband	12½ acres; 7,281 tons	90,000	—	—
Do. do.	81⅓ acres; 7,281 tons	—	593,600	—
Do. (Gilmerton)	49½ acres; 9,707 tons	—	480,000	—
Do. (Gilmerton)	58 acres; 9,707 tons	—	—	561,000
Do. do.	43 acres; 7,281 tons	—	—	313,000
Do. do.	260 acres; 4,680 tons	—	—	1,216,800
(4) Gilmerton Blackband in the Lower Limestone Group	116½ acres; 4,072 tons	—	475,400	—
Do. do.	225 acres; 4,072 tons	—	—	917,200
		185,000	2,117,400	4,646,000

All these ironstones are in the Limestone Coal Group except the last. The output of ironstone in Midlothian in 1913 was 22,903 tons, all from Coal Mines.

(1) Worked out above 100 fathoms; dies out to the north and is of doubtful occurrence to the south and east.

(2) Partly worked out above 200 fathoms; dies out to the north and south, but is good in depth to the east. Iron (raw ore), 23·5; silica, 8·37; alumina, 4·05; sulphur, 1·06; phosphorus, 0·41 per cent.

(3) In the Gilmerton district; dies out to the north and east; much faulted and workings flooded in 1875. In the Loanhead district; partly worked to 200 fathoms; dies out to the south and is unproved to the east. In the Clayband:—iron (raw ore), 34·1; silica, 2·99; alumina, 1·10; sulphur, 0·29; phosphorus, 0·47 per cent. In the Blackband:—iron (raw ore), 29·7, and silica 5·29 per cent.

(4) Abandoned in 1885; much faulted.

AYRSHIRE.

From notes by G. V. Wilson.

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Craigmark Blackband ...	700 acres; 3,500 tons	2,450,000	—	—
(2) Plann Blackband	640 acres; 1,560 tons	—	1,000,000	—

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—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(3) Moncur Musselband	360 acres; 4,000 tons	—	—	1,440,000
(4) Kilwinning Main Coal Ironstone	1,280 acres; 4,500 tons	—	—	5,750,000
(5) Dalmellington and Lugar Blackband	2,620 acres; 5,000 tons	1,500,000	—	6,200,000
(6) Do. do.	5,120 acres; 5,000 tons	3,200,000	—	20,000,000
(7) Logans Bands (calcareous claybands)	7,680 acres; 4,650 tons	—	—	30,750,000
(8) Garibaldi Ironstone (calcareous)	2,560 acres; 2,000 tons	—	—	5,000,000
(9) Dalry Clayband	640 acres; 4,300 tons	—	3,500,000	—
(10) Do.	11,200 acres; 4,650 tons	—	50,500,000	—
		7,150,000	55,000,000	69,140,000

The first six are in the Coal Measures, the remaining four are in the Limestone Coal Group.

The total output of ironstone from Ayrshire from Iron Mines and Coal Mines was 217,423 tons in 1913.

(1) Has been little worked; depth small over the area considered. Iron, 15·99; silica, 6·43; coaly matter, 50·29; sulphur, 0·95; phosphorus, 0·18 per cent.

(2) Of good quality; a considerable unworked area to the west of Kilmarnock. Iron, 31·5; silica, 2·5; phosphorus, 0·6; sulphur, 0·26 per cent.

(3) A carbonaceous bed associated with a clean coal. Iron, 30·78; silica, 2·5; alumina, 2·70; lime, 82·10; sulphur, 0·37; phosphorus, 0·20; loss on calcining, 44·75 per cent.

(4) Calcareous; abandoned on account of high sulphur-content.

(5) District of Dalmellington and Rankinston; faulted out to S.E. and N.W., mostly unproved to the N.E. Iron, 27·82; silica, 8·88 per cent.

(6) District of Lugar, Old Cumnock and Muirkirk; probably poor to the S.W., very deep to the W., and cut off by a fault to the N. The "proved reserve" lies at less than 300 fathoms deep, the "possible reserve" at 300 to 600 fathoms.

(7) Persistent over a large area, but variable in thickness and quality. Iron, 44·31; silica, 7·91 per cent. for the calcined stone.

(8) Worked as recently as 1914 at Glengarnock. Of good quality but variable. Iron, 47·54; silica, 11·30; sulphur, 0·16; phosphorus, 0·55 per cent.

(9) Worked up to 1897 in the district of Lugton and Caldwell at shallow depth. Uniform in thickness.

(10) Uniform in thickness over wide areas in the districts of Kilbirnie, Lochwinnoch, Glengarnock and Dalry. Iron, 25·7 to 28·89; silica, 7·62 to 9·70; alumina, 5·95 to 4·41; sulphur, 0·23 to 0·08; phosphorus, 0·56 per cent.

CENTRAL COALFIELD (RENFREW, LANARK, STIRLING, DUMBARTON AND PART OF LINLITHGOW).

From notes by M. Macgregor.

The following bands occur in the Coal Measures:—

Crofthead Slaty Blackband at base of Coal Measures.—A coal formerly wrought in several districts, but generally poorly developed or absent. Last worked in 1901.

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Armadale Slaty Blackband, a few feet under Colin Carn Coal.—A local seam not now worked.

Clayband Balls above Ball Coal in the Falkirk, Armadale and Fauldhouse Coalfield—Output in 1913, Falkirk coalfield, about 3,600 tons; Armadale, about 31,000 tons.

Clayband above Mill Coal in Falkirk Coalfield.—Output in 1913, nil; in 1917, 9,333 tons.

Clayband Balls above the Upper Drumgray Coal.—Occasionally worked on a small scale.

Kiltongue Mussel-shale and Ironstone.—The ironstone is thin and poor; the shale above it has been worked locally for oil.

Bellside Blackband.—Local in the Newhouse-Wishaw district. Working long discontinued.

Roughband Clayband above the Virtuewell Coal.—Locally developed; occasionally worked with the coal.

Airdrie Blackband, widely sought after in the past, but none now available. In other districts it exists as a coal (Blackband Coal).

Palacecraig Blackband. Strictly local to Airdrie; now exhausted.

The following table relates to ironstones in the Millstone Grit and Carboniferous Limestone Series:—

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Bowhousebog Blackband ...	80 acres; 3,120 tons	—	249,000	—
(2) Curdly Clayband	1 acre; 4,200 tons	—	4,200	—
(3) Black Metals of Kilsyth (= Banton Claybands)	14,640 acres; 4,500 tons	—	—	65,880,000
(4) Do. do.	9,600 acres; 3,600 tons	—	—	34,560,000
(5) Do. do.	10,240 acres; 4,200 tons	—	5,000,000	38,000,000
(6) Do. do.	900 acres; 5,400 tons	—	4,860,000	—
(7) Do. do.	15,360 acres; 4,800 tons	—	—	73,750,000
(8) Johnstone Clayband ...	1,230 acres; 300 tons per inch	—	7,380,000	—
(9) Do. ...	1,000 acres; 300 tons per inch	—	—	6,000,000
(10) Do. ...	1,920 acres; 300 tons per inch	—	100,000	11,520,000
(11) Do. ...	9,600 acres; 300 tons per inch	—	—	51,840,000
(12) Raesgill Claybands... ...	130 acres; 3,600 tons	—	468,000	—
(13) Do.	130 acres; 2,400 tons	—	312,000	—

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	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(14) Househill Claybands ...	5,120 acres; 300 tons per inch	30,000	200,000	36,864,000
		30,000	18,573,200	318,414,000

The first two ironstones are in the Millstone Grit and the last two are in the Lower Limestone Group. The remainder are in the Limestone Coal Group.

The total output of ironstone in the Central Coalfield in 1913, from Iron Mines and Coal Mines, was 349,107 tons.

(1) and (2) Irregular and only locally workable.

(3) District of Kilsyth, Banton, Nethercroy and Kirkintilloch. A thick constant bed of blaes with bands of ironstone. Iron, 34·75 (calcined, 48·78); silica, 8·26; alumina, 4·78; lime, 3·70; manganese oxide, 1·23; magnesia, 3·74; sulphur, 0·014; phosphorus, 0·42; loss on calcination, 28·50 per cent.

(4) N.W. of Glasgow. A thick and constant bed of blaes with 12 to 14 inches of ironstone.

(5) N.E. of Glasgow. In places 15 to 17 inches of ironstone in 4 to 5 feet of blaes. Development under the Central Coalfield little known and yield per acre theoretical. Iron about 40 per cent.

(6) District of Denny. Generally one seam to 11 to 14 in., with thinner seams close above or below.

(7) District of Denny. The estimate of "possible reserves" relates only to the area covered by the few available boreholes.

(8) Paisley-Johnston district. Seam constant. Iron, 45·88; silica, 12·93; alumina, 8·73; lime, 5·82; phosphoric oxide, 3·05 (calcined ore).

(9) Cardonald and Corkerhill. Seam constant in thickness and character.

(10) Nitshill. Seam constant in thickness and character.

(11) N.W. of Glasgow. The estimate is founded on the supposition that a thickness of 18 in. of ironstone in a 4 to 5 ft. working is constant over the area proved by boreholes.

(12) Carluke district. The upper or 5-ft. working, with about 12 in. of ironstone; locally workable.

(13) Carluke district. The lower or 3-ft. working with about 8 or 9 in. of ironstone; locally workable.

(14) Nitshill and Hurlet district. The ores pass into thin limestones to the N. and N.W.; extension to the E. unknown.

The Main Ironstone of Cadder and the Kilsyth No. 3 Blackband of Dumbreck Colliery is still worked. The output in 1913 from the former was 73,437 tons, and from the latter, 27,806 tons. In neither case are the reserves large. Recently the working of a blackband has been begun at Bo'ness and thin seams of blackband occur in association with workable coals at Giffnock and elsewhere. The well-known Banton Blackband was last worked at Nethercroy in 1914. All of these are in the Limestone Coal Group.

Revision in the Central Coalfield of Scotland.

Braehead and Auchengray, Lanarkshire (Sheet 23).

Mr. Hinxman was engaged for a few weeks during the summer in revising the maps of the Carboniferous area south of the

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Wilsontown fault, between Forth, Braehead and Auchengray (Sheet 23). This revision was necessary to complete the resurvey and description of Area VI. of the Central Coalfield of Scotland.

A complete sequence of the Calciferous Sandstone strata of this region is probably present in the district of Auchengray, there being no evidence of any unconformity between the rocks of that series and those of the Upper Old Red Sandstone along the west side of the North Medwin valley.

A freshwater limestone, regarded as the equivalent of the Burdiehouse seam, occurs close to the surface on the east side of Stallashaw Moss.

The higher seams of the Lothian oil-shales—the Fraser, Raeburn and Fells Shales, are present in the area north of the Wilsontown fault, between Cobbinshaw and Auchengray, and have been worked at Tarbrax. On the south side of the fault the positions of the Fells Shale and Houston Coal have been proved in bores near Ampherlaw and Muirhall; it is therefore possible that workable shales may be present in the ground along both sides of the railway south of Auchengray Station, but there is no evidence to show whether these shales extend westwards beneath the limestones of the Braehead basin.

An interesting feature of the Carboniferous Sandstone in this district is the occurrence, near the top of the Series and 3 to 4 fathoms below the Main Limestone, of a group of clayband ironstones, which were formerly wrought to a considerable extent under the name of the Kilpothall or West Sidewood Ironstones. They appear to be confined to a limited area on the south-east margin of the Braehead basin and thin out rapidly towards the west.

The Carboniferous Limestone rocks of the Braehead district include possibly the whole of the Lower Limestone Group, but the presence of any seam belonging to the succeeding Limestone Coal Group, in the ground south of the Wilsontown fault, cannot be demonstrated.

The Main Limestone and the Coal beneath it were extensively worked in the past along the south side of the basin, but the quarries have long been abandoned. The Raesgill Ironstones of Carluke, which lie between the two lowest Hosie Limestones, were also wrought in past times to the north of Braehead and near East Sidewood; a considerable area of these ironstones is probably available, at no great depth from the surface, to the north of the line of old open-cast workings. The outcrops of the seams within the basin are a good deal interrupted and displaced by faulting.

Refractory Materials.

Fireclay.

Ayrshire.—In last year's Summary of Progress, p. 15, mention was made of a peculiar hard non-plastic fireclay lying immediately above the Millstone Grit Lava Series in North Ayrshire. Near Saltcoats and Stevenston the rock contains a high percentage of alumina and is exceedingly refractory, but as the outcrop is

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traced east towards Kilmarnock the quality deteriorates considerably as is shown by the following tests:—

Saltcoats	Seger cone	36
Stevenston	„ „	35
Smithston	„ „	32
Lugton Water	„ „	31
Annick Water	„ „	29
Fenwick Water	„ „	30-31

Mr. Wilson reports that the clay is now being mined and worked near Saltcoats and Stevenston, and the practical tests to which the finished articles have been subjected show that they are of exceptionally high quality.

Arran.—On the published one-inch Geological Survey map of Arran, volcanic rocks are shown occurring at the position of the Millstone Grit. As the bauxitic fireclay which occurs at this horizon in Ayrshire is now being worked, and may prove to be valuable, a visit was paid to Arran by Mr. Wilson. The presence of a similar seam of clay at this horizon was ascertained.

The section exposed in the Merkland Burn near Brodick Castle is as follows:—

Red fakes and blaes	
Pink bauxitic fireclay	5 ft.
Hardish decomposed red lava	4 „
Soft „ „ „	16 „
Thin red limestone	1 „

The clay is of the same general character as that on the mainland, but is rather harsher to the touch, pink in colour, and contains numerous strings and grains of hæmatite. Tests have shown that it is not so refractory as the fireclay of Saltcoats and Stevenston.

Wigtownshire.—At Low Knockglass, about $1\frac{3}{4}$ miles south-west of Stranraer, a similar fireclay is exposed near the base of a thin series of rocks, apparently of Upper Carboniferous age, resting unconformably on Silurian strata and covered by Permian brockrams and red sandstones. The material is of a pink or lilac colour, like that of Arran, but is rather softer to the touch. At least 3 ft. is seen, but the section must be opened up before the full thickness can be ascertained. Samples have been taken and arrangements made for practical tests of the quality of this clay.

Report on Scottish Occurrences of Felspar.

By Dr. R. Campbell.

Sutherland.—The pegmatites reported on by Mr. Dinham[1] were revisited and additional specimens collected. A thick vein on the south side of the Durness-Rispond road merits attention since it contains less plagioclase and biotite than the normal pegmatites of the Beinn Ceannabeinne area. It forms a conspicuous crag on the hillside just behind the shepherd's house at Ceannabeinne, $\frac{3}{4}$ mile east-south-east of Sangobeag. For a distance of at least 140 yards it maintains an average thickness of over 25

[1] 'Special Reports on the Mineral Resources of Great Britain,' *Mem. Geol. Surv.*, vol. v, 2nd edition, 1917, pp. 1-14.

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feet. It is understood that the Beinn Ceannabeinne property has been leased, and in 1917 several trial-quarries had been opened and the most highly felspathic portions of the pegmatites were being separated by hand-picking.

Other pegmatites were examined in the country to the north of Loch Inchard. Of these the occurrence most likely to prove of economic value is a vertical dyke at Cnoc-an-Tuir about half-way between Rhiconich and Achriesgill. It can be traced from the side of the Kinlochbervie road in an east-south-east direction for 200 yards in a series of knolls. The outcrop is lenticular, varying in width from 20 feet to 35 yards. In the widest portion inclusions of gneiss are rather numerous. Thirty feet may be taken as a moderate estimate of the average thickness of good pegmatite-material. This dyke is a coarse-grained pegmatite showing little sign of crushing. The dominant constituent is pink microcline with which are associated quartz, buff-coloured albite-oligoclase, and a little mica. The microcline and quartz occur partly as a coarse graphic intergrowth, partly as separate crystals, and the latter mineral forms veins up to a foot in thickness. Analyses of the alkali content of the average material of the pegmatite and of the soda spar were made by Mr. Radley; the former yielded K_2O—9·35, Na_2O—2·05, the latter K_2O—2·74, Na_2O—7·13 per cent. The average rock would be classed as a spar of Grade 2; much of the microcline could be separated readily by hand-picking to give a spar of Grade 1; small quantities of the soda spar might also be hand-picked, and might suit the requirements of glass-manufacturers who desire a spar rich in soda. The pegmatite is distant less than 200 yards from the shore of Loch Inchard.

Argyllshire (*Strontian District*).—Numerous dykes and veins of white and pale-pink pegmatite traverse the schists and granites between Ben Resipol and Loch Sunart. They have a general north and south trend and are usually vertical or nearly so; they thicken and thin out rapidly giving characteristic lenticular outcrops. In the limited time at his disposal Dr. Campbell was able to make only a partial examination of these pegmatites, but three occurrences may prove to be of economic value.

(*a*) About $\frac{1}{4}$ mile north-east of the farm of Ardarie and 4 miles west of Strontian there occurs a dyke of highly felspathic pegmatite in which some years ago two trial quarries were opened for the exploitation of mica. The dyke can be traced for a distance of over 200 yards. Near a small stream, about 80 yards west of the quarries, it has a breadth of about 20 feet with rather numerous inclusions of the country-rock. Southwards it rapidly increases in thickness, and for the last 130 yards of its course, until it is lost under the boggy ground in the direction of Loch Sunart, the outcrop maintains an average width of about 35 feet of coarse pegmatite almost free from inclusions of schist.

The rock is in great part a coarse graphic intergrowth of quartz and pinkish-white felspar. Locally, however, the quartz and felspar occur separately in bands up to 4 feet or more in thickness. The dominant felspar is a pinkish-white microcline-perthite en-

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closing small scales of muscovite. White albite-oligoclase is present in smaller amount. Large plates of muscovite also occur, but are confined to a few definite layers; in one of the quarries two courses of muscovite were noted, one about 10 inches thick, the other ranging from 1 inch to a foot in thickness. Individual books of mica attain a breadth of as much as a foot.

The bulk of the felspar occurs as a graphic intergrowth with quartz and would give a spar of Grade 2. But a very considerable yield of most pure microcline-perthite (with less than 5 per cent. of quartz) might be obtained by hand-picking. A market might be found for the mica and the quartz as well as the felspar. The probable minimum quantity of pegmatite available is estimated as 50,000 tons. The chief difficulty in transport would be in getting the quarried material across the uneven hill-slope to Ardarie. From Ardarie to the shore of Loch Sunart at Camasine is a distance of a little over a mile by road.

(*b*) A dyke of white pegmatite varying in width from 18 to 20 feet, forms a conspicuous feature on the north shore of Loch Sunart on the west side of Point Sron-na-Saobhaidh. Cutting vertically through the schists and trending 10° W. of N. it can be traced up the face of the cliff to the Strontian-Salen road and appears again in a succession of knolls in an oak wood beyond. The rock consists essentially of white felspar (partly microcline-perthite, partly oligoclase) and quartz with subsidiary amounts of muscovite and biotite and an occasional accessory garnet. It has the highly irregular texture characteristic of fine-grained pegmatites, and at the same time shows considerable local variation in the relative amounts of the chief constituents. Both the striated oligoclase and the microcline-perthite are white in colour and it has not been found possible to obtain a satisfactory estimate of the relative amounts of the two felspars. Biotite becomes locally rather abundant in some of the finer-grained parts of the rock, and a few garnet-rich patches have been noted. Such portions form a small proportion of the total rock-mass and could be got rid of by hand-picking. Inclusions of the adjacent schists are so few in number as to be almost negligible.

Little selection would be necessary to obtain iron-poor and alkali-rich material suitable for the enamel industry, but it is doubtful whether spar suitable for extraction of potash could be obtained in any quantity even with careful hand-picking. There is deep water close inshore where the dyke occurs. The estimated probable quantity of pegmatite available without pumping or mining is 100,000 tons.

(*c*) At a point about two miles north-west of Strontian Parish Church and by the side of the old road which leads to the lead mines at Coire an t-Suidhe there occurs an exposure of pegmatite which merits further investigation. The outcrop is about 900 square yards in extent and the rock resembles the Ardarie pegmatite described above. It is distant about 3½ miles from the shore of Loch Sunart.

The Strontian property has been leased by the Scottish Felspar Company, and quarrying operations have already been commenced.

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Banffshire.—Dr. Campbell visited the pegmatite-dykes mapped by Dr. Horne on the Banffshire coast east of Portsoy. The largest of these, and the only one likely to prove of economic value, occurs on the west side of East Head. The dyke is vertical and can be traced almost continuously for about 300 yds. For 80 yds. it forms the face of the 25-ft. beach cliff, trending north-east and south-west. Keeping the same direction it can be followed in a succession of small knolls which rise above the level of that beach until, as the high-water line is approached, it begins to trend north-north-east and south-south-west. At high-water mark the width of the outcrop is 45 ft.; near the south-western end of the dyke it is 25 ft. Further to the south-west isolated knolls of pegmatite appear on the moorland tract between the 100 ft. and 200 ft. contours. These are in alignment with the above dyke and may indicate a prolongation of its course inland under a covering of drift.

The pegmatite is brick-red in colour. It consists essentially of a fine graphic intergrowth of microcline and orthoclase with quartz, with tourmaline, muscovite, biotite, and acid plagioclase as accessory constituents. Of the accessory minerals tourmaline is most abundant, and much of the rock from its richness in that mineral would be unsuitable as raw material for the enamel, glass, and pottery industries. An analysis of the alkali content by Mr. Radley gives K_2O—8·90 per cent., and Na_2O—2·48 per cent.; the rock therefore merits consideration as a possible source of potash.

The estimated minimum quantity of pegmatite available from that portion of the dyke which extends from the 25 ft. beach cliff to high-water mark is 7,000 tons. Assuming that the dyke continues along the line indicated by the isolated outcrops described above, and assuming further that it maintains an average thickness of 18 ft. in its course inland, a much greater quantity, say 50,000 tons, may be available. The dyke is situated less than a mile from Portsoy Harbour and railway station. There is a road to within 500 yards of the outcrop, and a footpath with easy gradient for the remainder of the distance. The path could be converted into a road suitable for carting at very little expense.

Aberdeenshire.—Dr. Campbell also visited the granites of the Peterhead and Tillyfourie districts of Aberdeenshire. He concluded that from the point of view of the present enquiry the rock most likely to prove of value is the red Corrennie granite.

Situated on the south side of the Aberdeen-Alford railway at Tillyfourie Station the Corrennie quarries have been opened on a narrow belt of granite which connects the Hill of Fare granite of Deeside with the Benachie and Cairn William mass to the north. The Corrennie rock is salmon-pink in colour, very highly felspathic, and almost free from ferro-magnesian minerals, which are represented only by an occasional small crystal of biotite. The felspar is mainly microcline and orthoclase, acid plagioclase being subordinate in amount. An analysis of the alkali-content by Mr. Radley shows that the average rock contains K_2O—8·02 and Na_2O—1·37, with a trace of LiO_2.

The Corrennie quarries have been worked for over 20 years by

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Messrs. John Fyfe & Sons, Ltd., and the spoil-heaps would furnish an immediate supply of many thousands of tons. For practical purposes the available supplies may be regarded as unlimited. A steel wire-rope haulage system is used to run the material from the quarries to a siding at Tillyfourie Station, the distance from which to Aberdeen is 24 miles by rail.

Kincardineshire. — Dr. Campbell visited the pegmatites, granites, and felsites on the Kincardineshire coast between Girdleness and Cove Bay. None of the pegmatites is of sufficient thickness to be regarded as of economic value; the granites carry much more biotite than the Corrennie rock. The most promising occurrence from the point of view of the present enquiry is a felsite at the Cave of the Red Rocks. The felsite occurs as a gently inclined sill, intrusive in the gneisses, which dip inland at about 10°. It is seen in continuous section at and near the top of the cliff, following the course of a series of indentations in the coastline for about 700 yds., thinning towards the south and ending abruptly to the north, and maintaining an average thickness of 15 ft.

The rock is a pale brick-red felsite showing scattered small rounded quartz phenocrysts in a fine-grained, compact groundmass. Thin sections show that the dominant felsitic groundmass is uniform in composition, consisting essentially of a microcrystalline aggregate of quartz and orthoclase with numerous scales of muscovite. Ferromagnesian minerals are absent, but their former presence in small amount may be indicated by the occurrence of occasional shreds of limonite. The alkali content of the average rock was found by Mr. Radley to be K_2O—4·67 per cent., Na_2O—3·53 per cent., along with a trace of Li_2O.

For a considerable part of its course the sill forms the summit of the cliff, and is free from, or nearly free from, cover. It is well-jointed, breaking readily under the action of the ordinary denuding agencies into large slabs up to a foot in thickness. The most suitable point for quarrying preparations is about 150 yards from the railway (opposite the farm of Mains) and from the adjoining road which leads to Cove Bay Railway Station, about $1\frac{1}{2}$ miles distant. From Aberdeen the distance by rail is 3 miles.

Samples of the rocks described above have been submitted for trial to various manufacturers of enamel and pottery, and to the Potash Supplies Department of the Ministry of Munitions, for analysis and experiment.

THE MID-SCOTLAND SHIP CANAL.

Much information bearing on the alternative routes of the proposed Mid-Scotland Ship Canal was collected during the year by Mr. Dinham.

In connection with the northern or Lomond Route, some 80 bore-journals were collected, giving a general idea of the nature of the Carse deposits at different points south-east of Stirling, and showing that here rockhead is not likely to be touched except perhaps near Carnock House. A short report also was prepared on the coal-seams in this part of the Stirlingshire coalfield.

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With regard to the Leven Valley branch scheme, the alluvial deposits of the River Leven were examined, and interesting evidence collected regarding the depth of the sub-alluvial valley at Dumbarton. The Vale of Leven occupies the site of what appears in preglacial times to have been a fjord, joining the Clyde on the east side of the Dumbarton Rock, not, like the course of the present river, on the west side. The buried northern slope of the Rock descends, at first almost precipitously, to a small ledge at about 160 ft. below Ordnance Datum, and beyond this it falls more gradually. North-east of the Rock, at a point within 190 ft. of its nearest visible side, the old valley floor reaches a depth of at least 200 ft. below sea-level, the slope therefore being more than 45°. Nearer its centre it is known to be at least 250 ft. deep, and we may note that the greatest proved depth to rockhead in the buried Kelvin Valley, at Drumry, N.E. of Clydebank, is 240 ft. below O.D. The material with which the Leven fjord is now filled up consists almost wholly of mud, probably largely glacial, running sand and occasional boulders. Only at the top, down to 20 or 30 ft. below sea-level are beds of finer sand, and occasionally gravel, met with; these pass up-stream into distinct fluviatile terraces which tend to coalesce at the mouth of the valley, where they have perhaps been re-sorted by tidal action.

At the northern end of the valley, where the Leven issues from Loch Lomond at Balloch, proof has been obtained that sand and gravel, with finer muddy deposits toward the base, descend to at least 25 ft. below sea-level.

Work was subsequently undertaken on the southern or Kilsyth, so-called 'Direct' Route. This lies almost entirely within the Central Coalfield, and upwards of 250 bore-journals were available for showing the nature of the surface-deposits from Grangemouth to Clydebank. The geological structure and composition of the Carboniferous strata involved were outlined in a short report, illustrated by sections. The following is a summary of the results of the investigation so far as the surface-deposits are concerned.

At the east end of the canal, between tide-marks, old workings in the Grangemouth collieries show that boulder clay extends to 210 ft. below Ordnance Datum. The route at once crosses from the preglacial valley of the Forth into that of the Carron, the rock-ridge between them, here not higher than 100 ft. below O.D., being overlain by boulder clay beneath the Carse deposits of mud and red clay. The greatest recorded depth of the preglacial Carron valley along the route is near Carronbank, where rockhead is not higher than 270 ft. below O.D. Here, and elsewhere in this old valley, the boulder clay under the Carse clays is separated from the rock by about 100 ft. of sandy deposits. Beyond Carron Grange the route runs along the northern slope of the buried valley, and then, crossing to its southern side, leaves both the preglacial and the present-day Carron valleys at a point a little below Bonnybridge. In cutting the canal, rock should first be met with hereabouts, near the farm of Gateside, and is likely to appear thence continuously at least as far as

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Inchterf, between Kilsyth and Kirkintilloch—a distance of 14 miles. Up to Kelvinhead the line runs in the valley of the Bonny Water, the rock-bottom of which is not certainly known to be anywhere deeper than 15 feet above O.D. The buried channel which runs along this valley is not in general as broad as that of the Carron, and appears to be especially constricted at Wyndford Lock, and again at Craigmarloch, where its visible sides, formed by a dolerite sill, are less than 200 yards apart. It is evident that the proposed canal, with gentle curves of 2 miles radius, will not coincide everywhere with the centre of the buried valley, and will therefore intersect varying thicknesses of the surface-deposits, consisting mainly of sand and gravel, and ranging along this stretch from 5 and over 100 feet. The rock-sides will in general consist of sandstones and shales, but whinstone (quartz-dolerite) is met with at Craigmarloch and, in the northern bank at least, should line the canal for half a mile in the neighbourhood of Auchinstarry. The canal then crosses the dolerite sill at Auchinvole, and near this spot will locally have to be cut down at least 130 feet into whinstone rock.

West of Auchinvole House the route enters the great buried channel of the Kelvin, and rockhead rapidly descends. The mansion is said to be built upon trap, while less than 100 yards away the alluvium is reported to be 120 feet in thickness. Rockhead at this last place is consequently only about 30 feet above O.D.; at Twechar it is probably the same, and descends to sea-level S.W. of Inchterf. From here to Torrance direct evidence is scanty, but it is unlikely that rockhead will rise higher than 20 feet above O.D., while it may descend as low as 40 feet below that level. The surface-deposits consist generally of sand and gravel, though "brown till and boulders" have been recorded opposite Kirkintilloch. At Meadowbank rockhead rises to 60 feet above O.D., but rapidly plunges to 170 feet below beyond Torrance Bridge. From this point rockhead will lie for some distance well below the bottom of the canal, being about 200 feet below sea-level at Buchleyford. Here the route begins to leave the Kelvin buried channel and passes obliquely across its south bank, rockhead accordingly climbing rapidly to 80 feet above Ordnance Datum, half a mile N.E. of Killermont House. At this point the surface-deposit is only 16 feet thick. Rockhead then gradually falls to 18 feet above O.D. at South Westerton, and from Cloberhill onwards to the Clyde is not likely to occur again in the cutting. The surface-deposits throughout this final stretch consist mostly of soft clay with some sand and gravel.

III.—PETROGRAPHICAL WORK.

Reports have been furnished to other Government Departments on various matters of economic or military importance, including world-sources of radium, chromite, cobalt and selenium, and on sources of potash-felspar in the Colonies. A number of specimens of German concrete from Flanders was submitted by the War Office to the Geological Survey for examination with a view to the identification of the pebbles and rock-fragments of which the concrete was composed. The result went to show that all the

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pebbles could be matched in the Rhine gravels, but that there was a notable absence of Belgian rocks. Some of the rock-fragments were recognised as having come from a German source. The Report has been published in Foreign Office Papers, 'Miscellaneous, No. 2 (1918).' Subsequently specimens of cement were submitted; these were compared, as regards their microscopical and chemical characters, with a large series of British cements, and the results communicated to the War Office.

Specimens from the South Sandwich, the Falkland and South Shetland Islands, and Graham Land have been reported on for the Colonial Office. An improvement in the construction of aeroplane-compasses has been devised for the Admiralty by Dr. Thomas with the co-operation of Mr. Radley. The description of silica-rocks, hearth-sands and dolomites for the first of the volumes on Refractory Materials, has been completed.

IV.—CHEMICAL WORK.

In connection with the work on Refractory Materials, 53 further analyses have been completed by Mr. Radley. One mineral from California has been completely analysed for the Scientific and Industrial Research Department, and some specimens from the Falkland Islands examined for the Colonial Office, as regards their value as fuel or as sources of oil. The following estimations of alkalis in some Scottish igneous rocks have been made:—

Lab. No.	550	551	552	553	554
K_2O ...	8·90	2·74	9·35	4·67	8·02
Na_2O ...	2·48	7·13	2·05	3·53	1·37
Li_2O ...	not found	not found	not found	trace	trace

Anal. E. G. Radley.

Lab. No. 550 (Slice No. 19628). Vertical dyke in schists, Banffshire coast; west side of East Head and three-quarters of a mile N.E. of Portsoy. 1-inch map 96.

Lab. No. 551. One of the constituents of a pegmatite-dyke. Roadside at Cnoc-an-Tuir, between Rhiconich and Achriesgill, N.E. shore of Loch Inchard, Sutherland. 1-inch map 113.

Lab. No. 552. Vertical dyke in gneiss. Same locality as Lab. No. 551.

Lab. No. 553 (Slice No. 19625). Sill intrusive in gneiss. Cave of the Red Rocks, 1⅓ miles N.E. of Cove Bay Railway Station, Kincardineshire. 1-inch map 77.

Lab. No. 554 (Slice No. 19626). Granite-intrusion, Corrennie Quarry at Tillyfourie Railway Station, Aberdeenshire. 1-inch map 76.

V.—PALÆONTOLOGICAL WORK.

England and Wales.

The fossils collected during the year were obtained principally from borings. The identification of the Mesozoic fossils from deep borings in Kent has been completed by Dr. F. L. Kitchin and Mr. J. Pringle.

A large number of the specimens presented by the Geological Society has been transferred to the Museum-cases; among many

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type-specimens are included fishes from the Old Red Sandstone. Many drawings of fossil fishes, prepared under the supervision of L. Agassiz, and now in the possession of the Geological Society, have been examined by Mr. Allen and found to include a large number of unpublished figures, to the originals of which Agassiz gave names without publishing adequate descriptions. A considerable number of these specimens have been identified in the above-mentioned collection, and have been placed in the Museum for reference.

The most notable donation received during the year is a valuable collection of invertebrate fossils from the Coal Measures, presented by the late Capt. L. Moysey, R.A.M.C. This includes arthropods of much rarity and interest, some of which have been figured and described.

The following specimens in the Museum have been figured and described:—

In the Quarterly Journal of the Geological Society, Vol. LXXII.

By Dr. A. Smith Woodward, F.R.S., V.P.G.S.

Edestus newtoni *A. S. Woodw.*, pl. i, p. 1.

By H. Bolton, Esq., M.Sc., F.R.S.E., F.G.S.

Pseudofouquea cambrensis (*Allen*), pl. iv, figs. 4, 5, text-fig. 6, p. 59.

By Stanley Smith, Esq., D.Sc., F.G.S.

Phillipsastraea hennahi (*Lonsdale*), pl. xxii, figs. 1–4, p. 288.

In the Transactions of the Royal Society of Edinburgh, Vol. LI.

By F. R. C. Reed, Esq., M.A., Sc.D., F.G.S.

Obolus audax *Reed*, pl. i, figs. 7, 8, p. 798.
Paterula balclatchiensis *Dav.*, pl. i., f. 19, p. 800.
Rhinobolus? balclatchiensis *Reed*, pl. ii, f. 7, p. 802.
Acrothele medioradiata *Reed*, pl. iii, figs. 20, 21, p. 813.
Orthis (Harknessella) vespertilio *J. de C. Sow*, pl. xi, figs. 3, 4, p. 862.
„ ? nina *Dav.*, pl. xi, f. 8, p. 863.
Strophonella penkillensis *Reed*, pl. xviii, f. 14, p. 900.
Triplecia craigensis *Reed*, pl. xx, f. 5, p. 908.
Mimulus? incertus *Dav.*, pl. xx, f. 22, p. 911.
Clitambonites complectens (*Wiman*), *var.* albida *Reed*, pl. xxi, f. 20, p. 916.

Scotland.

No systematic palæontological work was done, but fossils were collected from the cores of borings and from sections the stratigraphical position of which was in doubt. On the evidence thus obtained it was possible to base important conclusions.

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VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Museum remained closed, except for special enquiries. Work has been continued upon the Report on Silica-rocks, ganister, hearth-sands and dolomite.

A considerable number of specimens of British Iron Ores was sent in by the Survey Field Staff.

Among the donations, attention may be drawn to the presentation by the late Captain L. Moysey, R.A.M.C., referred to on p. 40.

List of Donations during the year 1917.

Abbott, Dr. G., M.R.C.S.—Five specimens of Concretionary Magnesian Limestone from Fulwell Hill, Roker, and Carley Hill, Durham. (Two figured: *see* 'Nature,' February 8th, 1917.)

Acton, A., Esq.—One specimen of fused silica-brick from Wrexham, and one specimen of colour-marking in Millstone Grit, from Flintshire.

Bell Bros., Ltd., Messrs.—Iron Ore, core of Main Seam, from Kilton Mine.

Bolckow, Vaughan & Co., Ltd., Messrs.—A series of specimens of Yorkshire Iron Ores.

Burls, H. T., Esq.—(*See* Petroleum Research Dept.)

Burr, Dr. M.—A specimen of Caucasian Oligocene with shells, and Tertiary shells from the Corinth Canal.

Colonies, The Under-Secretary of State for the.—Five Rock-specimens, possibly from the South Sandwich Islands; also twenty-nine rock- and mineral-specimens from the South Shetland Islands and Graham Land.

Congleton Silica Brick & Ganister Co., Ltd., Messrs., The.—Samples of Dry Ganister, Silica Sand, Fireclay, Silica-rock and Millstone Grit.

Craven, C. S., Esq., M.Inst.C.E.—Eighteen Mesozoic fossils from Bamba, on the Niger, East of Timbuctoo.

Crookshank, Lieut.-Col. A. A., R.E.—Two teeth of *Odontaspis elegans* Ag., from the Landenien? of N.E. France.

Davies, Messrs. T. J., & Co.—A series of samples of Sleeves, Nozzles, Stoppers, etc.

Delaney, Messrs. J., Ltd.—Dolomite from Threshfield, Yorkshire.

Fox, Roy & Co., Messrs., Ltd.—A sample of enamel made from Meldon Stone.

Frodingham Iron Company.—Eight brachiopods and lamellibranchs from the Northampton Sands of Woolsthorpe, Grantham.

Garwood, Prof. E. J., F.R.S.—Twenty-seven specimens of the Pre-Cambrian Rocks of Herefordshire, Radnorshire and Shropshire.

Girty, G. H., Esq.—Five specimens of *Diaphragmus* from the Upper Mississippian of Muskingum Co., Ohio.

Greenwood, F., Esq.—A specimen of Graphite from Borrowdale, Cumberland.

Gwersyllt Silica Brick Co., Ltd.—Four samples of Silica Bricks.

Hall, Lieut. T. C.—One specimen of diabase dyke from the Old Shaft, Callow Hill, Minsterley, Shropshire.

Hallimond, A. F., Esq.—One fused Silica Brick from Hutton, West Witton, Durham; also three specimens from the furnace-bottom in the Malleable Steel Works, Stockton-on-Tees.

Hutchinson, Dr. A.—One limestone-specimen from the Limestone Quarries, Burlescombe, Devon.

Jenkin, Capt. C. J., R.E.—Nineteen plants from the Coal Measures, near St. Omer, France.

King, Capt. W. B. R.—A fragment of *Inoceramus* and specimens of Foraminifera from the Dièves (Lower Turonian) of Souchez, Northern France.

Marriott, Major, R.A., D.S.O.—A crystal of Jarrowite from the River Clyde.

Ministry of Munitions of War (through A. E. Russell, Esq.).—Five specimens from Nickel and Arsenic Mine, Talnotry, Kirkcudbrightshire.

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MOYSEY. CAPT. L., R.A.M.C.—Two specimens of Chalk impregnated with Cement from Upstreet Colliery Sinking, Kent; also a large series of fossils, mostly from the Coal Measures, including figured and described specimens.

NEALL, J. A., ESQ.—An ammonite from Malreward, Somerset.

NOBLE, CAPT. A. H.—Sixteen igneous rocks from Mexico.

OSMAN, C. W., ESQ.—Three specimens of inclusions in granite from near Chagford, Dartmoor, Devon.

OSWALD, DR. F., F.G.S.—A geological Model of Nimrud Volcano, Armenia: scale one inch = one mile.

PEDDLE, C. J., ESQ., M.SC., F.G.S.—Samples of glass made from Muckish Mountain, Lynn, Aylesbury, Huttons Ambo and Fontainebleau Sands, together with specimens of the sands.

PERKIN, DR. F. M., Ph.D., F.I.C., F.C.S.—Specimens of Geyserite from Stadur Reykjanes, S.W. Iceland.

PETROLEUM RESEARCH DEPARTMENT (PER H. T. BURLS, ESQ.).—Specimen of core of Kimmeridge Clay with fossils from boring No. 1 at Holme, and Kimmeridge Clay with fossils from Smith's Pit, West Winch, south of King's Lynn.

ROUTLEDGE, S., ESQ., M.A.—Eight Rock-specimens from Socorra Island, and eleven Rock-specimens from Pitcairn and Easter Islands.

RUSSELL, A. E., ESQ.—(*See* Ministry of Munitions of War.)

RUTHERFURD, W. G., ESQ.—A series of Agates mounted as brooches, to illustrate the production of artistic effects by the selection of suitable natural stones; also a large collection of cut and polished Agates from New Zealand, Australia, Scotland and other parts, together with a number of cut and rough opals; also a specimen of Florentine inlaid work.

SHERBORN, C. D., ESQ.—A large specimen of Tin Stone from the South Crofty Mine, Camborne, Cornwall.

TATHAM, CAPT. ATHOL.—Five specimens of Mollusca from Cretaceous rocks in the Menabe District, West Coast of Madagascar.

TOWNLEY, MISS.—One *Caninia cylindrica* E. & H. from the Carboniferous Limestone of Sligo.

WALFORD, E. A., ESQ.—One *Neaera* and one *Cyathophora bourgueti* (Defr.) from Sharp's Hill, Hook Norton.

WILLIAMS, S., ESQ.—Two specimens of Riebeckite Rocks from Nigeria.

WILSON, A., ESQ.—Six specimens of Quartz from the Carrock Fell Mines, Troutbeck, Cumberland.

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

(*a*) *One-inch Maps* (*New Series*).

(Colour-printed, price 1*s.* 6*d.* each.)

Sheet 100, Sheffield. (Temporary Edition.)

A colour-printed Drift Edition of the following Sheet has been issued in place of the hand-coloured edition:—

Sheet 62 (Old Series 93 N.W.). Harrogate.

(*b*) *Six-inch Reference Maps.*

The following 27 standard copies of six-inch quarter-sheets have been made from the field-copies, and are available for reference:—

Westmorland, 28 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 38 N.W., N.E., S.W., S.E.; 39 N.W., N.E., S.W., S.E.

Yorkshire, 265 N.W., N.E.; 277 N.W., N.E., S.W., S.E.; 285 N.W., N.E., S.W., S.E.; 297 N.W. (Yorks. part only).

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APPENDIX I.

ON A DEEP BORING, NEAR MARKET WEIGHTON.

By W. Gibson, D.Sc.

Several trial borings for coal have been made south of the Humber, even though the cover of Triassic and Permian rocks was known beforehand to be of considerable thickness. North of the Humber, and approaching Market Weighton, the Jurassic and Cretaceous formations show a marked attenuation, and borings near Selby prove the Coal Measures to extend north of the Ouse. If, then, the Trias and Permian had also proved thin, the Coal Measures might have been accessible near Market Weighton.

The present explorations were carried out in 1912-14 by Messrs. J. and T. Mitchell, to whom we are indebted for access to the cores and journal and for permission to publish this account.

Two borings were put down, of which the first was abandoned at about 1,000 ft. depth. The second hole was commenced a few yards away and was carried down to a depth of 3,100 ft. The site is 440 yds. north of the Reformatory School, 2½ miles south-west of Market Weighton, on the north side of the Market Weighton Canal (6-inch Ordnance Map, Yorks, 209; 1-inch New Series, Sheet 72, Ed. 1903), at a height of 30 ft. above O.D. It is 14¾ miles N.E. of a boring for coal at Barlow (The Concealed Coalfield of Yorkshire and Nottinghamshire, *Mem. Geol. Surv.* 1913, pp. 72-73) and 17 miles nearly due north of a boring near Scunthorpe, which is said to have proved Coal Measures (P. F. Kendall, *Rep. Brit. Assoc.* for 1910, p. 608). Continuous cores were drawn from the first hole; in the second, percussion drilling, with occasional recourse to a diamond crown, was adopted. Below 2,100 ft. almost continuous cores were obtained, and at 3,100 ft. a core, 3¼ inches in diameter was produced. No appreciable dip could be determined and, since the deflection of the hole was shown to be slight, the thickness of 3,100 ft. proved in the boring can be taken as the true thickness.

The following account is abstracted from the boring-journal:—

	Thickness. Ft.	In.	Depth. Ft.	In.
Superficial, 2 ft.				
Clay and stones	1	6		
Gravel	–	6	2	–
Keuper Marl, 634 ft.				
Red sandy marl and mixed marl	78	–	80	–
Red sandy marl with grey plies [skerries]	30	–	110	–
Red marl with gypsum and red marl	59	–	169	–
Conglomerate	8	–	177	–
Red marl with some gypsum and bastard sandstone	36	–	213	–
Conglomerate	4	–	217	–
Red and variegated marl, with hard bands and some gypsum	145	–	362	–
Gypsum	–	4	362	4
Blue and red marl	5	–	367	4
Gypsum	–	1	367	5
Variegated marl with bands of gypsum	75	1	442	6
Blue variegated marl	1	6	444	–
Variegated marl with gypsum	161	–	605	–
Red variegated marl	31	–	636	–

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	Thickness. Ft.	In.	Depth. Ft.	In.
Keuper Waterstones, 68 *ft.*				
Grey sandstone	14	–	650	–
Red sandy marl	6	–	656	–
Soft grey sandstone	20	–	676	–
Red and grey sandstone	28	–	704	–
Bunter Sandstone, 1,425 *ft.*				
Red sandstone	218	–	922	–
Variegated sandy marl	66	–	988	–
Red sandstone	186	–	1,174	–
Red sandstone with marl partings	631	–	1,805	–
Conglomerate	25	–	1,830	–
Red sandstone with marl	25	–	1,855	–
Conglomerate with limestone	24	–	1,879	–
Red sandstone	157	–	2,036	–
Mottled marl	22	–	2,058	–
Red sandy marl	15	–	2,073	–
Red sandstone	12	–	2,085	–
Red sandstone with marl	37	–	2,122	–
Soft grey sandstone	1	–	2,123	–
Red sandstone with marl	6	–	2,129	–
Upper Permian Marl, 212 *ft.*				
Red mottled marl with gypsum	173	–	2,302	–
Red marl with blue stones [rock salt]	39	–	2,341	–
Upper Permian Limestone, 141 *ft.*				
Limestone [pale grey and cream-coloured]	20	–	2,361	–
Limestone with anhydrite	9	–	2,370	–
Limestone [pale limestone with casts of lamelli-branchs]	112	–	2,482	–
Middle Permian Marl, 29 *ft.*				
Rock salt	23	–	2,505	–
Dark red marl with anhydrite	4	6	2,509	6
Dark mottled marl	1	6	2,511	–
Lower Permian Limestone, 589 *ft.* 3 *in.*				
Limestone [giving off a strong smell of petroleum]	48	9	2,559	9
Limestone with anhydrite	17	6	2,577	3
Grey limestone	169	–	2,746	3
Brown and grey limestone with anhydrite	133	–	2,879	3
Grey anhydrite	221	–	3,100	3

End of Boring.

Summary.

	Thickness. Ft.	in.
Superficial	2	–
Keuper Marl	634	–
Keuper Waterstones	68	–
Bunter Sandstone	1,425	–
Upper Permian Marl	212	–
Upper Permian Limestone	141	–
Middle Permian Marl	29	–
Lower Permian Limestone	589	3
	3,100	3

The small thickness of the superficial deposits is in agreement with neighbouring tracts (J. W. Stather, *Rep. Brit. Assoc.* for 1907, pp. 325-328).

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The Keuper Marls in the first boring consist of a homogeneous mass of red variegated marl, streaked with gypsum and with occasional interbedded thin layers of hard, red and grey sandstones (skerries). The so-called 'conglomerates' of the second boring are likely to have been red marl containing rounded concretions of lime ('race'). A thickness of 634 ft. was proved, but the boring entered the marls about 200 ft. below their summit.

Below the Keuper Marls the coarse, light-grey sandstones, 68 ft. thick, agree with similar beds that occur beneath the Keuper Marl of Nottinghamshire and are there classed with the Keuper Waterstones.

Below the Waterstones the boring traversed red sandstones down to 2,129 ft. depth, bands of red marl, one of them 22 ft. thick, occurring at intervals. Pebbles of quartz and other rocks are absent, though pellets of red marl give the appearance of conglomerates on the outside of cores. This may be the explanations of the 'conglomerate' at 1,830 ft., but it is difficult to assign that at 1,879 ft. to any part of the Bunter formation as revealed in borings north of the Humber. The sandstones are all fine-grained, becoming more loamy and micaceous in the lower part. They are chiefly red in colour, and grey sandstones, such as occur in several borings—notably at Strensall, in the Vale of York—are absent.

The Upper Permian Marl is considered as commencing at the first band of red marl with gypsum, but there is little difference in appearance between these marls and those in the Bunter. Brine issued from the boring about the depth of 2,302 ft., and stringers of rock-salt were found in the cores below this depth.

The Upper Permian Limestone consists chiefly of pale cream-coloured limestone, with occasional bands of fine grey limestone. A few obscure casts of shells were obtained by Mr. Manson.

The Middle Permian Marls are much thinner than those found in other borings of the Humber region, but resemble them in character and in the local development of a bed of rock-salt.

The Lower Permian Limestone varies much in texture and colour. It is usually compact, unfossiliferous, and contains large clots of amorphous anhydrite. This mineral also occurs separately as crystals, sometimes arranged in a spherulitic manner. The solid compact mass, 221 ft. thick, of grey and bluish-grey anhydrite, from 2,879 ft. depth down to the bottom of the boring, is exceptional. At Selby and Barlow borings, bands of anhydrite, 18 and 20 ft. thick, occur in the Upper Permian Marls, and a thin band in the Upper Limestone, but in the Lower Limestone there are only interspersed anhydrite and gypsum. At Market Weighton 368 ft. of limestone lies above the anhydrite, and as a greater thickness of limestone is found in other borings to the south-west it is possible that the anhydrite was deposited at Market Weighton while limestone was laid down to the south-west in the manner suggested for the thick mass of anhydrite at Hartlepool (C. T. Trechmann, *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 184-218). The boring, however, fails to reach the

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base of the Permian, and the anhydrite may represent the basement shales found in borings to the south.

The results obtained by the Market Weighton boring dissipate any hopes that the Triassic and Permian formations thin away north of the Humber; on the contrary, each of these formations, when compared with other borings to the south, has shown a marked expansion. It might be suggested that the Trias and Permian rocks of Market Weighton owe their thickness to their occupying a local depression, but the easterly slope of the floor, as determined in borings to the south-west of Market Weighton, is sufficient to carry the floor 100 ft. below the bottom of the bore-hole.

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APPENDIX II.

On a Boring in Deep Drift at Gosmore, near Hitchin, October, 1917.

By A. Strahan, Sc.D., LL.D., F.R.S.

New Series Ordnance, One-inch Sheet 221. Old Series Geological, Sheet 46 S.E.

Long. 0° 16′ 30″. Lat. 51° 55′ 42″.

Above O.D. 270 ft.

Communicated by Messrs. Le Grand and Sutcliff.

	Thickness. Ft.	Depth. Ft.	
Dug well	44	—	
Drift, clay and stones	16	60	
Flints and large stones	20	80	water-level varies
Gravel and sand	6	86	
Sand	11	97	
Clay with grains of chalk	29	126	
Hard rock	8	134	
Sandy clay	6	140	
Sand and flints	12	152	
Sand, clay and stones	34	186	
Sand and veins of chalk	12	198	
Grey clay or chalk	20½	218½	
Clay, sand and stones	1½	220	
Clay (light-blue)	to 30	250	

No water was obtained from the lower part of the borehole, but a sufficient supply for the farm was got from the gravel at a depth of 77 to 97 ft.

A small specimen of the light-blue clay, from a depth of 220-250 ft., consisted of a uniform pale-bluish grey silty clay, free from large grains.

The boring is situated about 40 ft. above the outcrop of the Melbourn Rock, and, allowing 170 ft. for the thickness of the Lower Chalk, the base of the Chalk might have been expected at a depth of 210 ft., *i.e.*, at a height of 60 ft. above O.D. An old boring in Hitchin, however (between the Priory and the Church), is described as having reached the base of the chalk at a depth of 229 ft.,[1] or 9 ft. below O.D., and as having passed through 214 ft. of Gault into Lower Greensand. The identification of chalk in this old boring was attended with some doubt.

If the estimate of the position of the base of the chalk is correct, the bottom of the new borehole must be 36 ft. below that base; if the old record is to be trusted it must be about 20 ft. below that base. No chalk in place has been traversed in the boring, but the clay at 220-246½ ft. might be Gault, though its appearance is more that of a stoneless band in boulder-clay.

The borehole is situated near the western margin of the drift-filled channel described by Mr. W. Hill in the *Quart. Journ.*

[1] 'Geology of the London Basin,' *Mem. Geol. Surv.*, 1872, pp. 453, 454.

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Geol. Soc., vol. lxiv., 1908, p. 8. It lies between Ransom's Brick Yard, where the Gault was reached under 340 ft. of Drift, at 68 ft. below O.D., and a boring made by the Hitchin Joint Hospital Board, where chalk was reached under 159 ft. of Drift, at 159 ft. above O.D.

The Henlow boring, described by Mr. Hill in the *Proc. Geol. Assoc.*, vol. xxiii, 1912, p. 223, and in the Summary of Progress for 1912, *Mem. Geol. Survey*, 1913, p. 89, is situated in the same drift-filled channel, but about 5¼ miles N.N.W. of Gosmore. A red mottled clay, the origin of which is unknown, was found at Henlow. Its absence is to be noted in all the borings farther south.

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APPENDIX III.

On a Deep Boring for Coal at Kelham, Nottinghamshire.

Published by permission of the Coal and Iron Development Syndicate, 24, Budge Row, Cannon Street, E.C. 4.

The boring at Kelham was made in the years 1908-12 in search of coal. The site is on the left bank of the Trent, 1½ miles W.S.W. of the Midland Railway Station at Newark, in the New Series 1-inch Map, Sheet 126, and the Old Series Geological Map, Sheet 70. The surface of the ground is about 40 feet above Ordnance Datum, and the dip of the strata was inappreciable.

The Coal Measures were reached at a depth of 1,401 ft. from the surface, and the strata down to that depth have already been described in 'The Water Supply of Nottinghamshire' (*Mem. Geol. Surv.*), 1914, p. 81.[1] The remainder of the section is now made known by permission of the Coal and Iron Development Syndicate through Mr. J. Ford, M.I.Min.Eng., F.G.S., under whose superintendence the boring was made. The details supplied by Mr. Ford are supplemented by observations (in square brackets) made by Dr. Gibson during the progress of the operations.

Kelham Borehole.

From a section communicated by Mr. J. Ford (partly abridged as regards the strata between the coal seams).

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Superficial Deposits; Triassic and Permian rocks...	1,401	–	1,401	–
Coal Measures—				
Shale with ironstone, and thin sandstones ...	44	6		
Coal and dirt...	1	6		
Shale	33	6		
Sandstone	8	–		
Shale	18	–		
Coal 3 ft. 2 ins. Parting 2 ins. Coal 1 ft. 0 ins. Parting 3 ins. Coal 1 ft. 11 ins.	6	6	1,513	–
Shale	26	6		
Coal	–	4		
Shale with ironstone	18	2		
Coal and fireclay	1	6	1,559	6
Shale, etc.	32	9		
Coal	1	–	1,593	3
Fireclay and shale with ironstone	53	3		
Bind, fireclay and shale	33	6		
Coal	1	7	1,681	7
Fireclay	10	5		
Coal	1	2	1,693	2

[1] The thickness of one of the sub-divisions of the Pebble Beds in this account is wrongly given as 338 feet. It should be 438 feet.

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	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Fireclay and shale	22	4	1,715	6
Dark-greenish rock [igneous rock]	77	5	1,792	11
Fireclay and shale with ironstone	26	–		
Coal	–	9		
Fireclay	13	7		
Coal	–	5		
Black shale	–	2		
Coal	–	6	1,834	4
Fireclay and shale with ironstone	80	–		
Shale and bind	82	8		
Coal and bat	1	2	1,998	2
Fireclay, shale and bind	140	5		
Coal	–	6	2,139	1
Shale and bind	64	5		
Shale with ironstone	92	2		
Coarse grey sandstone	2	3		
Fireclay	11	11		
Dark shale [*Lingula, Pterinopecten*]	3	4		
Coal [Alton Coal or Halifax Hard Mine]	1	5½	2,314	7½
Sandstone, stony bind, fireclay and shale	39	4½	2,354	–
[Millstone Grit]—				
Hard whitish sandstone	12	4	2,366	4[1]
Sandstone with iron-pyrites and band of shale	10	1	2,376	5
Yellow coarse-grained sandstone, yielding saline water	20	2	2,396	7
Hard grey sandstone	3	4	2,399	11
Conglomerate with crystalline pebbles [quartz]	1	–	2,400	11
Sandstone	–	9	2,401	8
Conglomerate	–	3½	2,401	11½
Dark shales	26	3½	2,428	3
Dark shales with stone-bands	5	–½	2,433	3½
Fireclay	4	–	2,437	3½
Grey sandstone	2	–	2,439	3½
Coarse brown sandstone yielding oil	13	1	2,452	4½
Coarse conglomerate	–	4	2,452	8½
[Millstone Grit or Carboniferous Limestone Shales?—]				
Dark shales and bands	30	2½	2,482	11
Hard sandy bind with ironstone-bands	7	10	2,490	9
Dark shale	7	6	2,498	3
Conglomerate	–	7	2,498	10
Hard white sandstone	1	6	2,500	4
[Carboniferous Limestone Shales—]				
Black shale	2	–	2,502	4
Hard sandy bind with ironstone	14	8	2,517	–
Black shale	15	–	2,532	–
Hard white stone [Crowstone]	10	6	2,542	6
Dark shales with iron-bands [*Lingula* and Goniatites]	56	1	2,598	7
Conglomerate	1	–	2,599	7
Sandstone	–	8	2,600	3
Limestone, coralliferous and yielding hot water	18	9	2,619	–

The lowest strata, 18 ft. 9 in. thick, were found by Dr. Gibson to consist of calcareous and fossiliferous shales with an earthy limestone, penetrated for 1 ft., at their base. The limestone yielded a fragment of a compound coral. The 'hard-white

[1] From here downwards the section is given in full detail as communicated.

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stone' at a depth of 2,542 ft. 6 in. was a siliceous band or 'Crowstone,' characteristic of the upper part of the Carboniferous Limestone Series.

The igneous rock met with at a depth of 1,715 ft. 6 in. is described in 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 1913, p. 58. It may be classed as a teschenite, with some unusual characters.

The section proved in the borehole admits of more than one interpretation, and the identity of the seam proved at 1,513 ft. is in doubt. By Messrs. Ford M. Deacon, and C. R. Hewitt it is regarded as the Top Hard Seam, but the fact that the Alton Coal was identified only 800 ft. below it suggests the possibility of its being a seam much lower in the series than the Top Hard.

The Lower Coal Measures extend to a depth of 2,354 ft., and no more than 148 ft. of strata at most can be classed as Millstone Grit, or scarcely an eighth part of the thickness of this subdivision at its outcrop, upwards of 26 miles farther west.

It is necessary, therefore, to infer that the boring passed through at least one fault. The identification of the so-called Top Hard as one of the lower seams and a supposition that the Millstone Grit is faulted against the Carboniferous Limestone Shales, would account for the observed facts, and there is independent evidence that the borehole is situated on or near a line of fault which throws the beds down to the S.W. An alternative supposition is that attenuation on a rapid scale takes place eastwards both in the Middle Coal Measures and in the Millstone Grit.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

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OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

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FOR 1918.

I.—*INTRODUCTION.*

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., Director.

Work in connection with the War.

The cessation of hostilities on the signing of the Armistice on 11th November, 1918, leads to the expectation that the normal work of the Geological Survey may be resumed at no distant date. At the commencement of the War the three districts of (1) Denbighshire and Shropshire, (2) Warwickshire and Staffordshire, (3) London and the South-East of England, were in hand. In 1915 the work in the London and South-East district was suspended and a series of Special Reports on the Mineral Resources of Great Britain was commenced. In 1916 work on the other districts was suspended, and the energies of those members of the staff, who had not gone on military or other duty, were concentrated thenceforward upon problems connected with the War, or upon matters of immediate economic importance. The present time seems suitable for placing on record the work of the Survey during the period of hostilities.

The history of each member of the staff, who was accepted for military or other duty with the Forces, is given in the following list:—

Geologists.			
Dixon, E. E. L.	... Lieutenant (T.)	Royal Garrison Artillery	—
Bailey, E. B.	... Lieutenant	Royal Garrison Artillery	Mentioned in despatches. Military Cross. Chevalier Legion of Honour. Croix-de-Guerre with Palm. Twice wounded.
Anderson, E. M.	... Sapper ...	Royal Engineers ...	... Wounded.

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Geologists.			
Carruthers, R. G.	Lance-corporal	Tank Corps	—
Bromehead, C. E. N.	Private ...	Duke of Cornwall's Light Infantry	Wounded.
Cunnington, C. H....	Lieutenant	Machine Gun Corps ...	Invalided out of Army, Oct., 1917. Died 26 April, 1918.
Richey, J. E. ...	Captain ...	Royal Engineers	Military Cross. Wounded.
Eastwood, T. ...	Lance-corporal	Royal Army Medical Corps (Sanitary Section)	—
Pocock, R. W. ...	Lieutenant	Royal Garrison Artillery	—
King, W. B. R. ...	Captain ...	Royal Welsh Fusiliers (attached to Engineer-in-Chief, G.H.Q.)	Mentioned in despatches. O.B.E.
Wray, D. A. ...	Lance-corporal	Royal Army Medical Corps (Sanitary Section)	—
Read, H. H.... ...	Corporal...	Royal Fusiliers	—
Whitehead, T. H. ...	Captain ...	Suffolk Regiment (transferred to General List and attached to Intelligence Corps)	Wounded.
Evans, R. du B. ...	Captain ...	Shropshire Light Infantry	Wounded. Prisoner of War
Assistant Clerk.			
Frisby, P. A. ...	Captain ...	Suffolk Yeomanry ...	—
Fossil Collectors.			
Eckford, R. J. A. ...	Corporal...	Royal Scots and Royal Engineers (Special Brigade)	Wounded.
Manson, W.... ...	Deck Hand	Royal Naval Reserve (T.)	—
Haldane, D.... ...	Lieutenant	Royal Scots	—
General Assistants.			
Rhodes, J.	Corporal...	Royal Air Force	—
Stewart, A. P. ...	Private ...	Royal Scots	—
Attendants.			
Morgan, S.W. ...	Reg. Qrtr.-Mstr. Sgt.	London Regiment (London Irish Rifles)	—
Couper, G. L. ...	Corporal...	Royal Engineers (Carrier Pigeon Service)	—
Hepple, D. W. ...	Private ...	18th Hussars	Wounded. Prisoner of War.
Draughtsmen.			
Torkington, G. G. ...	Private ...	Cameron Highlanders ...	Wounded.
Bruce, W. G. ...	Lance-Corporal	Royal Engineers (Field Survey Battn.)	—
Trowbridge, H. G. S.	Bombardier	Royal Field Artillery ...	—
Kidd, J.	Corporal...	Royal Engineers	—
Labourers.			
Wheaton, E. ...	Sergeant...	3rd Hussars	—
Brooker, J. F. ...	Corporal...	King's Own Scottish Borderers	—

The first of the economic investigations to be taken in hand were those required for the preparation of the 'Special Reports on the Mineral Resources of Great Britain.' These amounted, in fact, to a stock-taking of our home-resources of all minerals

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of economic value. By the end of 1918 seven volumes had been published, and for five of these second editions had been issued. Two were passing through the press, and six volumes on iron-ores, besides other Memoirs on lead-mining, etc., were in an advanced stage of preparation. The demand for these reports leads to a belief that they have met more than a temporary want, and that they will be of lasting value provided that they can be kept up to date.

Of the other activities of the staff during the War, some have been mentioned in previous 'Summaries of Progress,' but many have been hitherto regarded as confidential. The following list includes the more important services which have been rendered to other Government Departments during the period of the War, in connection with matters arising out of the War:—

Notes on the obtaining of drinking-water at short notice in the Chalk and Tertiary strata on the Western Front.

Pamphlet on 'Sources of Temporary Water Supply in the South of England and the Neighbouring Parts of the Continent.' In this connection W. B. R. King was detailed subsequently from the Staff to serve as Geologist on the Western Front.

Preparation of a Geological Map of Belgium on the scale of 1 : 160,000.

Report on the geological character of the ground in Belgium and the North of France and a detailed account of existing water-supplies.

Consultation on water-supply in Gallipoli. This led to three Geologists of the staff (C. H. Cunnington, R. W. Pocock, T. H. Whitehead) being detailed for geological work in Gallipoli.

Report on sources of road-metal in France.

Consultations on the making of tube-wells and the use of sand-screens in boreholes.

Report on water-levels in Chalk.

Preparation of sets of characteristic fossils for use at the Western Front.

Transference of a set of Geological Maps of Belgium on the scale of 1 : 40,000 from the British Museum to the Museum of Practical Geology, and of the Museum of Practical Geology set to the Western Front.

Consultations on the construction of seismographs for locating camouflets.

Report on German concrete from the Western Front, and on the source of the rocks used in it.

Report on German cement from the Western Front.

Preparation of a Geological Map and Section of Le Cateau battlefield.

Preparation of a Geological Map and Section of the Aisne battlefield.

Report on suitability of sand on the Western Front for making concrete.

Report on squeezing-out of clay in dugouts.

Report on water-supply in islands in the Firth of Forth.

Report on methods of tunnelling in Chalk.

Report on the cause of sores on the hands of tunnellers at the Western Front.

Three maps of the World showing sources of economic minerals.

Report on Mineral Resources of Austria-Hungary.

Report on wolfram ores in England.

Report on materials suitable for points and cups of aeroplane-compasses.

Reports on selection of quartz-crystals for Anti-Submarine Division of the Admiralty.

Examination in France of a consignment of quartz-crystals from Madagascar and reporting on same.

Superintendence by the Petrographer of the examination and selection of quartz-slabs by officers of the Anti-Submarine Division.

Report on proposed Mid-Scotland Ship Canal.

Report on a prize-cargo.

Report on borings for oil at Scremerston.

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Consultation on coal in Asia Minor.
Report on suitable valleys for airship-sheds.
Report on sources of radium, uranium-ores, pitch-blende and carnotite.
Report on caves for storage in England.
Collecting and reporting on Scottish fireclays.
Report on occurrences of magnesite at home and abroad (enemy countries excluded).
Report on occurrences of iron-pyrites in the United Kingdom.
Consultation on British phosphates.
Reports on borings for oil in Kimmeridge Shale.
Reports on occurrences of potash-felspar in Great Britain and on the suitability of some Scottish felspars for the manufacture of enamelled ware.
Consultations on sites for aerodromes.
" " munition-factories.
" " shell-store.
Report on decline in output of lead-ore in Great Britain.
Report on sources of selenium.
Report on fluorite and Iceland spar.
Consultation on potash in Alsace.
" " limestone suitable for certain purposes.
" " " for carbide manufacture.
Report (preliminary) on iron-ore reserves in Britain.
Correspondence on obtaining mica from Australia.
Report on underground caves for storing valuables, works of art, etc.
Correspondence on brine at Middlesbrough.
Report on Brown Coal near Cologne.
Macadam-supply on part of Western Front.
Short report on rocks near Archangel as a source of water.
Report on ornamental stones for cemeteries, and inspection of quarries in the Pas de Calais.
Search for potash-bearing rocks in North Wales.
Visiting and reporting on borings for oil by Messrs. Pearson & Son.
Report on occurrence of oil-gas in Gibraltar.
Report on sources of zircon.
Report on use of hexahedric crystals of iron-pyrites by the Germans.
Summary of analyses of British Iron-ores.
Maps showing Mineral Resources of British Empire.
Seven Maps showing localities and output of economic minerals in the United Kingdom.
Reports on borings, water-supplies and drainage, for several camps, aerodromes, etc., in England, Wales and Scotland.
Report on Geology of Gallipoli.
Report on oil-shale resources in Scotland.
Reports on the geology of the Scottish Highlands in conuection with water-power resources.
Consultations on the geology of certain districts suitable for small holdings in Scotland.
Report on mineral resources along suggested new railways in Scotland.
Report on limestone and marl for agricultural purposes in Scotland.

OIL-SHALE RESOURCES OF SCOTLAND.

In the 'Summary of Progress' for 1917, estimates were given of the resources of ironstone in Great Britain, and on two occasions estimates of the coal-resources of Scotland have been drawn up by Royal Commissions. It seemed desirable to frame an estimate of the oil-shale resources of Scotland on similar lines. Dr. Flett reports that the work of estimating areas and calculating thicknesses of the seams from the numerous bore-journals preserved in the Scottish office, was entrusted to Mr. E. M. Anderson, Dr. G. W. Lee and Mr. C. H. Dinham. In each case the revised six-inch geological maps were the basis adopted for the measurement of areas, but information obtained since the maps were published has rendered possible some corrections. By multi-

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plying the area over which a seam occurs by its average thickness and its mean specific gravity, figures were obtained which indicate the total maximum amount of oil-shale available, in the present state of our knowledge.

In these estimates all substances except oil-shale have been excluded, though oil can be obtained, and has been produced in Scotland on a small scale, from cannel-coal, torbanite or boghead, parrot-coal and parrot-shale, peat and ironstone-shale. As regards the thickness and quality which render a shale workable, it was decided to adopt as a standard the conditions which existed in the Scottish oil-shale industry during the ten years preceding the War. Accordingly, shales less than 3 ft. in thickness have been excluded, except in the few cases where their high quality or other favourable conditions have proved them to be of practical value. Also those areas have been excluded where the oil-shale, though present, is known to be of no practical value.

A rough approximation only to the amount of oil likely to be obtained from the oil-shale reserves by distillation is possible. A shale yielding a large quantity of ammonia sulphate can be distilled at a profit, even though it produces only 19 gallons of crude oil per ton. The richest shales yield 60 or 70 gallons per ton. In the Reports of the Mining Inspectors (Home Office) of recent years, 25 gallons of oil per ton is given as the average figure.

As regards depth, 300 fathoms has been taken as the present limit, for it happens, from the geological structure of the shale-fields, that the oil-shale resources below that depth are not large and would not greatly affect the totals obtained. Moreover, there are no bore-records which can serve as reliable indications of the occurrence, thickness and quality of these deep-seated shales. The limit has hardly been reached by the deepest shale-mines.

The figures are tabulated under the two headings, 'Proved and Probable Reserve' and 'Possible Reserves.' Those areas are regarded as 'proved' in which oil-shales are or have been worked on a commercial scale, and in which borings have shown that the shales maintain a workable condition. 'Probable areas' are those in which bores have established the presence of the shale in satisfactory thickness, and in which the geological structure is favourable, having regard to the absence of igneous intrusions with their injurious effects upon the shale.

Areas regarded as 'Possible Reserves' are those in which there are few or no bores, but where, on geological considerations, the shale may be expected to occur within 300 fathoms from the surface, and where there is no reason to doubt that it is of workable thickness and quality. Where the shale is likely to have been 'burnt' by igneous masses, or where it is suspected to be thin or of unworkable quality the whole area has been excluded. In framing estimates of possible reserves accuracy is impossible; the figures depend to some extent on the individual judgment of the geologist who takes the investigation in hand.

The number of shale-seams that have been worked in Scotland is considerable. Nearly all of them lie below the Scottish Carboniferous Limestone. The Torbanehill Boghead, the Levenseat Shale

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and the Kiltongue Shale lie above the Limestones, but have not been worked for many years. The principal shales are, in order from above downwards, the Raeburn, Mungle, Fells, Broxburn, Champfleurie, Dunnet, Camps and Pumpherston Shales. Of these seams, the more important, such as the Broxburn, Dunnet and Pumpherston may form a series many feet in thickness, which is separated into bands of good oil-shale with barren shale or blaes between, and each band may have a separate designation. In no district are all the shales present in workable development; often at the horizon of an oil-shale only a carbonaceous shale or shaly blaes is met with. The horizon is generally recognisable in the bores by the presence of some equivalent bed, or the oil-shale may be there but too thin to work. Oil-shales seem to be much more variable than coal-seams in these respects. It is noteworthy also that they do not pass laterally into coal-seams, but into dark carbonaceous shales yielding little oil.

Each of the important oil-shales is confined, as regards its maximum development in thickness or quality, to one or more areas, and in no one area is it usual to find more than three or four of the oil-shales in satisfactory condition. The numerous masses of intrusive igneous rock that have been injected into the oil-shale measures of the Lothians have destroyed a vast quantity of oil-shale by a process of subterranean distillation, and unfortunately the principal oil-shale seams—the Broxburn, Dunnet and Pumpherston—have all been extensively subjected to this action. Practically all areas where igneous intrusions are known to occur on or near the horizon of an oil-shale, have been omitted from the estimated reserves.

Other factors, not geological, affect the estimates of workable reserves. A shale that was unworkable before the war may, by changed commercial conditions, prove to be of value. As an example, the Pumpherston Shales, which are comparatively poor in oil but rich in ammonia, were once practically valueless, but now are of great importance. The future of oil-shale mining in Scotland would seem to depend principally on two factors—the rates of wages and the prices obtained for oil-shale products (oil, paraffin wax and sulphate of ammonia)—and any changes in these will directly affect the magnitude of the payable reserves of oil-shale.

Since 1873 the output of oil-shale from Scottish mines has been reported each year in the Home Office Returns. From 1873 to 1917, inclusive, it amounted to 89,401,981 tons, or, say, 90 million tons. The rise of Scottish oil-shale mining dates approximately from 1862, when the Torbanehill Mineral was exhausted, and an allowance of ten million tons is more than sufficient to cover all mining before 1872 and also the output for 1918 (not yet published). This gives 100 million tons as approximately the amount of shale that has been mined. To this must be added the amount lost in working from a variety of causes, say, 20%, or 20 million tons; giving a total of shale mined 120 million tons.

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The estimated reserves for the oil-shale fields are as follows: —

	Proved and probable. Tons.	Possible. Tons.
Midlothian	163,497,000	356,120,000
Linlithgowshire	416,539,000	371,211,000
Lanarkshire	16,730,000	67,000,000
Peebles-shire	5,120,000	28,020,000
Fifeshire		61,440,000
	601,886,000	883,791,000
Deduct amount already worked as above	120,000,000	
Total still available	481,886,000	

At present the output is approximately 3 million tons a year. Adding 20% for loss in working we get 3,600,000 tons as the yearly depletion of reserves.

This indicates 133 years as the duration of these Proved and Probable Reserves at the present rate of working. The Possible Reserves, if they all proved available would last for about 245 years under the same conditions, giving for all reserves a possible duration of 383 years. These figures which, of course, make no pretence to exactitude, may be compared with Mr. J. S. Dixon's estimate that the total available quantity of coal in Scotland in seams over 24 in. in thickness would maintain the present output for approximately 315 years.

II.—FIELD WORK.

POTASH-BEARING ROCKS IN NORTH WALES.

In the latter part of 1917 inquiries were addressed to the Geological Survey by the Controller of the Potash Production Department (Ministry of Munitions) with a view to ascertaining what rocks in North Wales contained sufficient potash to be worth a trial in cement-manufacturing. It was proposed to deliver to an important cement-works at Ellesmere a quantity of felspar containing not less than 6% of potash. In the process of cement-making the potash would be obtainable as a by-product. The questions addressed to the Geological Survey related to the known or possible occurrences of potash-bearing rocks in readily-accessible parts of North Wales, and also to the occurrences of rocks rich in soda but free from iron, and of rocks rich in alumina and free from iron. From a consideration of the specimens and analyses in our possession, it became clear that it would be necessary to make further examination of likely rocks in the field, to collect specimens from suitable sites, and to have special analyses made. The igneous rocks were regarded as the only probable source of potash in sufficient quantity, and as a first step in the search for potash the occurrences of soda-felsites and other rocks known to be poor in potash were ruled out. The field-work was further narrowed by consideration of transport. Finally it was arranged that the work of examining sites and collecting specimens should be carried out by Dr. A. H. Cox for the Geological Survey, and that he should co-operate with an officer of the Ministry of Munitions who would consider possibilities of trans-

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port, etc., from the localities selected. This work was carried out in July, 1918.

The specimens collected included:—

3. Rhyolite. Conway Mountain; roadside, quarry opposite Conway Morfa, worked by Conway Corporation.
4. Banded rhyolite. Conway Mountain; roadside, quarry west of Corporation quarry.
5. Blue rhyolite. } Conway Mountain. Conway Stone quarry worked
6. Creamy rhyolite. } by North Wales Granite Co. (Messrs. Brookes, Halifax.)
7. Green felsite, intrusive. Penmaenbach, roadside, west side of intrusion.
8. Banded granophyric felsite, intrusive. Penmaenbach, roadside, centre of intrusion.
9. Nodular rhyolite. Conway Mountain, old quarries on ridge.
12. „ Deganwy, Bryn-gosol Farm.
13. Porphyritic granophyre. Llanbedrog Point, near Pwllheli, worked by Cambrian Granite Co.
14. Dark granophyre. } Gwylwyr Quarry; roadside, 1 mile N.E. of Nevin,
15. Light granophyre. } worked by Penmaenmawr and Welsh Granite Co.
16. Granophyre. Middle quarry, Porth Nant, Nant Gwyrtheyrn, Llithfaen, worked by Kneeschal Lupton.
17. Granophyre. Trevor Quarry, Rivals, worked by Penmaenmawr and Welsh Granite Co.
18. White felsite. Roadside, 1 mile E. of Llithfaen.
20. Dust from dark granite-porphyry. Girn Ddu near Clynog, worked by Enderby and Stoney Stanton Granite Co.
21. White rhyolite. 6th milestone, roadside, S.W. side Llyn Padarn, Llanberis.
22. Blue rhyolite. Above Tunnel; roadside, S.W. side, Llyn Padarn, Llanberis.
23. Mixed rhyolites. Careg-yr-Undeb; roadside, S.W. side, Llyn Padarn, Llanberis.
26. Microgranite. Mynydd Mawr intrusion, lower crags N.E. of Llyn Cwellyn.
37. Pandy ash., Glynceiriog, worked by the Welsh Silica Co.

Specimens were also collected from various shales, and from the mica-schists of Anglesey, as follows:—

31. Mica-schist. Roadside quarry, ¼ mile E.S.E. of Gaerwen Station, Anglesey.
32. Mica-schist (fine-grained). West of Monument, Llanfair P.G.
33. Mica-schist (coarse-grained). Quarry, west end of Menai Bridge village.
2. Slates below volcanic series, east side of Penmaenmawr intrusion.
24. Purple slate. Glyn-rhonwe Quarry, Llanberis.
25. Blue slate, Llanberis Quarries.
27. Arenig slates. Porth Dimdde, Aberdaron.
29. Ashgillian shale. Old quarry, above Deganwy.
35. "White Shale." Coal Measures, Delph, Ruabon, worked by Wyndham and Phillips.
39. Bala shales. Roadside, ¼ mile S. of Glynceiriog.

For aluminous rocks low in iron, specimens were collected from the Coal Measure shales of Ruabon and Buckley.

From the specimens five were selected by the Potash Production Department of the Ministry for examination of the alkali-contents, and the following results were obtained:—

Sample.	K_2O Per cent.	Na_2O Per cent.
21	4·29	2·06
26	3·48	5·77
12	2·91	0·48
17	3·56	5·89
31	2·00	3·19

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Having regard to the low potash-content of these five, it was not regarded as necessary to have the other samples analysed. Further, it was found by tests that the hardness was a serious factor in the matter of output by the grinding plant. The three factors of low potash-content, hardness and distance from the Works did not suggest that the inquiry was worth pursuing further at the present time.

COPPER AND ARSENIC.

With a view to continuing the series of 'Special Reports on Mineral Resources,' inquiries into the resources of copper and arsenical ores were made in Cornwall and Devon by Mr. Dewey. Arsenical ores had hitherto been regarded as by-products, but the use of arsenic in some war materials has led to a sudden increase in demand and price. The two districts of Camborne-Redruth and Kit Hill-Calstock practically yield the entire output. Near Calstock, mines formerly worked for copper-ores left arsenical pyrites behind, and the stopes as well as the dumps are now being exploited for the ore. The reserves appear to be large.

Copper-ores are steadily diminishing in output, and the reserves are approaching exhaustion. A few tons, under 100 per annum, of copper-precipitate is being recovered from mine-drainage and dump-drainage waters, especially at the Levant Mine, St. Just, and the Devon Great Consols Mine near Calstock.

The output of the wolfram remains steady and depends upon the systematic development of the lodes. At East Pool the Rogers Lode maintains its richness, and has been proved recently at South Crofty. The recent fall in the price of wolfram may retard further rapid development.

SALT.

In the course of the year an investigation into all sources of salt in Great Britain was commenced by Dr. Sherlock, with a view to producing a 'Special Report.' The existence of rock-salt in the Keuper Marl of Cheshire, Shropshire, Staffordshire, Somersetshire, Lancashire, Yorkshire, and the Isle of Man, and in Permian rocks in Yorkshire, has long been known. The object of the investigation was to record the extent of these salt-beds, so far as it had been proved, the methods of working them, either by mining or the pumping of brine, and to ascertain what occasion exists to extend these methods into newly-proved ground. That the reserves are ample for all requirements, and that the output could be greatly increased, admits of no doubt.

The output of salt in 1913 is given in the Home Office Statistics as 2,247,758 tons (including 43,321 tons for Ireland), of which 214,573 tons were mined as rock-salt, the rest pumped as brine. An increase in output would depend upon the expenditure, which has to be kept at the lowest possible figure to render profitable the working of so low-priced a commodity as salt. Cheapness of working depends upon the existence of natural brine-runs, or upon the possibility of creating artificial brine-runs, a dry 'rock-head' being regarded as valueless. In Cheshire surface-water is turned

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into the old workings, which form convenient underground reservoirs; in other cases the strata overlying the salt-beds yield sufficient fresh water to keep a brine-run going when communication has been established by borings. The water quickly assumes the necessary condition of complete saturation, and its circulation in the salt-bed becomes freer as solution proceeds.

Among the more recently-discovered localities for rock-salt, mention may be made of a district E.N.E. of Northwich, and of an area at Heatley, near Lymm, in both of which the beds of salt are thick. A salt-bed proved in the borehole at Market Weighton, described in the Summary of Progress for 1917, pp. 42-45, has not yet been developed.

The possibility that salts of potash may occur in the brine or at the top of the salt-beds has been drawn attention to. Analyses have so far shown that these salts exist only in traces.

CANNEL IN GREAT BRITAIN.

The utilisation of cannel and other substances associated with coal-seams as a source of oil having been the subject of much discussion during the later stages of the War, the existing records of cannel-occurrences were published in Vol. VII. of 'The Special Reports on Mineral Resources of Great Britain.' It was understood that the account was preliminary, and that the quantity of cannel available, its value for the purpose named, and the possibility of raising, separating and treating it profitably, remained to be ascertained. As a fact, cannel, of late years, has been generally regarded as a waste-product, detrimental to the value of any coal-seam of which it forms part.

In order to make these investigations, the collieries in which the principal occurrences of cannel had been reported were visited: those in Cumberland by Mr. Smith, Northumberland, Durham and Yorkshire by Mr. Bromehead, Nottinghamshire, Derbyshire, Leicestershire, Warwickshire and North Staffordshire by Dr. Gibson, Lancashire by Mr. Smith and Mr. Pringle, South Staffordshire by Mr. Dewey, and North Wales by Mr. Pringle. The results of the inquiries will appear in a second edition of the volume referred to above, but it may be stated now that they do not point to the possibility of cannels furnishing more than a trifling addition to the oil-supply. A seam of cannel always takes a lenticular form, limited to a small definable area, ranging from a few acres to upwards of 30 square miles, and the most valuable of these lenticles have already been approximately exhausted. The possibility of raising, separating and treating the cannel as a profitable undertaking depends upon circumstances. In some cases the cannel, occurring, as it frequently does, at the top of a seam of coal, has to be left as a roof, or a heavy expense in timbering has to be incurred. Generally, the profit in the undertaking would depend also upon the value of the coke, and in this respect cannels are disappointing. The ash-content is usually high, especially in the impure cannels and 'canneloid' substances that have been suggested for experiment.

The mining of cannel in England and Wales, therefore, is not regarded as a sound commercial proposition, except so far as

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regards the small quantities that can be separated cheaply and used for special purposes, such as the enrichment of gas.

In Scotland a similar investigation is being carried on by Dr. Lee, with the assistance of other geologists. He furnishes the following preliminary account of the results:—

Many seams of cannel were worked in Scotland in the early days of the gas-industry, when a high illuminating gas was in demand, but of recent years they have been almost completely neglected, except where they occur as thin bands in workable seams of coal or ironstone. At Lochgelly in Fife the Upper Five Feet Seam and at Wellesley Colliery, Fife, the Pirnie or Earl David's Parrot were being mined in 1917 and sent to gas-works and oil-works in Scotland. Cannel is also being worked at Loanhead, near Edinburgh, where it forms part of the No. 1 and No. 2 Ironstone Seams. In a number of Scottish coal-mines cannel is being worked and sold with the coal with which it is associated, but it is not generally regarded as improving the value of the coal, though in blast-furnaces, gas-works and for steam-raising, the disadvantages are not so great as to preclude its use in certain proportions. In other cases where cannel is mined as part of a coal-seam it is picked out and sent to gas-works and oil-works. Occasionally it is used for building underground packs, or is cast back into the waste of the mine.

As cannel is not distinguished from other varieties of coal in the Statistics it is impossible to give the output. It is certain, however, that there is very little mining for cannel by itself. It is, in fact, regarded as an inferior variety of coal which was rather avoided by the mining engineer under the conditions which existed in the coal-trade before the war.

The number of seams containing cannel that have been worked is large. Many of those which were well known in the early days of the gas-industry, when cannel was in demand, were worked out and little information can be obtained regarding them, except from old reports. As sources of cannel in the future they are not likely to be of importance. Moreover, the cannel-rib varies greatly in thickness and may pass into ironstone. The correlation of the cannel-seams, especially those of the outlying fields like Muirkirk, Campbeltown and Douglas, is difficult. Some are recognised over large areas, such as that in the Splint Coal of Lanarkshire, and the Kiltongue Musselband and Cannel; others, though comparatively thick, cover only a small area, like the Earl David's Parrot of Fife or the Cannel Seam of the Douglas Castle Colliery. The following list contained the principal occurrences, arranged according to the coalfields in which they are found:—

FIFE.

Calciferous Sandstone Series.—A few thin seams of cannel of poor quality occur in these strata. Near West Pitcorthie, north of Anstruther, a compound seam of true oil-shale, blackband-ironstone and parrot-coal, 10 to 13 in. thick, was worked for a short period about the year 1870, and yielded about 20 to 25 gallons of oil per ton.

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Lower Limestone Group.—A band of cannel 5 in. thick usually accompanies the Blackband Ironstone Seam of Denhead, near St. Andrews.

Limestone Coals Group.—Borings through the lower part of the group, below the position of the Dunfermline Splint Coal have shown the occasional presence of thin seams of cannel associated with workable coals.

One of the lowest workable seams in the series was worked long ago at Drumcarrow, 4 miles S.W. of St. Andrews. The thickness was said to be 16 in. Another seam low down in the series occurs in the small Rameldry basin, near Kettle. Its thickness is given as 4 ft. in the Geological Survey Memoir on Central and Western Fife (p. 125), but in one locality at least it is known to have lost its volatile matter through the action of igneous intrusions.

The Glassee Coal, which is generally a household- or a steam-coal, contains, in the Lochgelly district, from 14 to 21 in. of cannel which is separated and sent to gas-works.

The Lochgelly Parrot Coal contains intercalations of cannel occasionally up to 3½ ft. thick, but as a rule 1 to 10 in. The yield of oil is about 34 gallons per ton. The Swallowdrum Coal of the Dunfermline district often passes into cannel, but is mostly worked out.

Over most of the Lochgelly field the Lochgelly Ironstone is a compound seam of blackband-ironstone and shale (oil-shale). The shale varies up to 16 in., and where richest has given 32 gallons of oil per ton.

The Inzievar Blackband Ironstone, workable only in the extreme west of Fife, near Oakley, is also associated with a cannel a few inches thick.

Upper Limestone Group.—A well-known cannel-seam extends from the extreme west of Fife, where it goes under the name of Cadell's Parrot, to the Lochgelly field where it is known as the Lochore Parrot. It was fairly extensively wrought until the middle of the last century at Oakley and at Lochore. At Lochore the seam varied from a few inches up to 2 ft. 2 in. and contained ironstone. There may be not inconsiderable reserves. In the Oakley district the indications are that the seam is largely wrought out.

The Capeldrae Parrot Coal, not far below the position of the Calmy Limestone, has long been known as a first-class cannel. It is essentially developed in the Capeldrae-Lochore basin, and was systematically worked in the latter half of the last century. The more readily accessible portions are supposed to be worked out, but many of the pits were abandoned before exhaustion on account of difficulties due to water. The seam consisted of two leaves, up to 1 ft. 6 in. and 1 ft. 8 in., respectively, of different quality, the best giving on distillation from 70 to 81 gallons of oil per ton.

The position of the Capeldrae Cannel seam has economic value in only one other district in West Fife—namely, at Oakley, where it is known as Overton or Oakley Parrot, and was wrought extensively.

Coal Measures.—The Lower Dysart Coal contains a band of cannel varying in thickness from 0 to 6 in. It is rich in oil

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of good quality, up to 92 gallons per ton, but the band could not be worked independently of the coal, which is of inferior quality.

At Westfield, north of Auchterderran, an oil-shale occupies a position probably corresponding to the Lower Dysart Coal. The shale is from 2 ft. 4 in. to 3 ft. 9 in. thick, forming the base of a seam of common coal. It was worked for oil-making for a few years in the 'sixties, and again in the 'eighties, yielding from 18·5 gallons to 30 gallons per ton. This seam may possibly extend over the whole of the Kinglassie field, an area of about 3 square miles.

The Pirnie or Earl David's Parrot occurs near the middle of the Coal Measures of Fife and covers 3 to 4 square miles between West Wemyss and Leven, dipping under the Firth of Forth. The thickness varies between 1 ft. 2 in. and 4 ft. 6 in. The quality is generally good, the yield of oil varying from 28 to 74 gallons per ton, with from 20 to 56 lbs. of ammonium sulphate. It was worked at Pirnie from 1864 to 1868 and retorted for oil at Methil. There are probably considerable reserves left, but they cannot be estimated as much of the field is under the sea.

In the Wemyss district a cannel-band occurred in the Parrot Coal, which lies from 10 to 15 fathoms above the Pirnie Parrot. The seam is now worked out in those areas where it contained cannel.

MIDLOTHIAN.

Lower Limestones.—In the cutting east of the bridge over the railway at Crossgatehall (6 in. Sheet 8 N.E.), there is an exposure of a parrot-shale 8 ft. thick. It was analysed by Dr. Pollard, the results being:—Moisture, 7·46%; volatile matter, 32·89%; fixed carbonaceous matter, 28·89%; ash, 30·76% and sulphur, ·85%. This seam deserves further investigation, as owing to its low geological horizon it possibly extends over large areas. Three-quarters of a mile N.E. of the exposure, bores have shown 'parrot shale' varying from 3 ft. 5 in. to 7 ft. 1 in. in thickness, which may be taken to be the same seam.

CARBONIFEROUS LIMESTONE SERIES. EDGE COALS.

The Arniston Parrot Seam, the lowest of the Edge Coals, is a compound seam of household-coal (Jewel Seam of some collieries) and cannel. The cannel occurs in the middle, and at Arniston and Newbattle Collieries it varies between 6 and 9 in. in thickness. It is of high quality, yielding on distillation up to 68 gallons of crude oil, with 54 lbs. of ammonium sulphate.

The No. 1 Ironstone of Loanhead and Dryden March contains from 12 to 15 in. of 'wild parrot,' and No. 2 Ironstone contains from 10 to 18 in., which was tried as a gas-producer and reported to be of inferior quality.

The Stairhead Seam at Niddrie is a compound seam of steam-coal, cannel and blackband-ironstone. The cannel ranges up to 2 ft. 6 in. in thickness and on distillation yields 22 gallons of crude oil per ton.

The Great Seam at Niddrie contains a cannel-band 1 ft. 2 in. to 2 ft. 6 in. thick, which thins out both north and south of Niddrie. On distillation it gives up to 56·5 gallons of crude oil per ton.

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The No. 3 Ironstone of Loanhead contains from 5½ to 8 in. of good cannel on the west side of the field, but this passes elsewhere into 'wild parrot.'

Other bands of cannel occur in the Edge Coals Group, especially in the Loanhead and Penicuik districts, but information is lacking regarding their value as oil-producers; as they are generally described as 'wild parrots' they are probably inferior in quality to the seams already referred to.

Upper Limestone Group.—The Edmondstone or South Parrot of the Niddrie and Loanhead areas is a first-class cannel, part of a compound seam. The cannel portion varies from 5 in. to 1 ft. 3 in. in thickness. On distillation it yields up to 56·5 gallons of crude oil per ton, with 73 lbs. of sulphate of ammonia. It has, however, the disadvantage of coking in the retorts.

Slightly higher up in the sequence, and underlying the 'Extra' Limestone, a rough cannel appears locally at the junction of the Dryden and Bilston burns. The position of the South Parrot may be represented on the east side of the basin by a parrot-shale 6 to 10 in. thick, seen in the old Cowden Cleugh Quarry. A specimen analysed by Dr. Pollard showed 49·62% of volatile matter.

Coal Measures.—A band of parrot-shale 7 in. thick occurs in the middle of the Parrot Rough Coal at Whitehill and Polton. It was frequently distilled, and is stated to have yielded 40 gallons of crude oil per ton.

LINLITHGOWSHIRE.

The Jewel Coal of the Bathgate district contains a band of cannel which is very variable, being absent in parts of the field and reaching 1 ft. in thickness in others.

The Six Foot Seam of Kinneil contains cannel from 0 to 10 in. thick, said to be of good quality.

The Lower Parrot and Ironstone, at a slightly higher level, includes cannel up to 14 in. thick, but the seam is probably mostly worked out.

The Balbardie Gas Coal Seam of the Bathgate district was once well known for the high quality of its associated cannel, about 7 in. thick, which for practical purposes may now be regarded as exhausted.

Upper Limestone Group.—The Castlecary Limestone is often overlain by an oil-shale, which, near Levenseat, is 15 in. thick, and was distilled for oil in the early days of the oil-industry. It yielded 33 gallons of crude oil per ton.

Coal Measures.—The celebrated Boghead or Torbanehill Mineral, yielding 120 gallons of crude oil per ton, is now exhausted. Another coal occurring higher up in the series was worked also as an oil-producer. It yielded 29·70 gallons of oil per ton.

CENTRAL COALFIELD.

The cannels and gas-coals of the Central Coalfield are, on the whole, much thinner than those of the East of Scotland, and the better seams are now practically wrought out.

The lowest seam is the Lillie's 'Shale' and Coal, which occurs in the Lower Limestone Group of the Paisley district. The thick-

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ness of the compound seam ranges up to 2 ft. and the 'shale' portion yielded 45 gallons of crude oil per ton. It was worked from 1870 to 1886 and there is probably little reserve left.

The Lesmahagow Gas Coal is practically exhausted, and so is the Wilsontown Gas Coal. The other cannels of this group in the Central Coalfield occur only as ribs in seams of ordinary coal or blackband-ironstone. Thus the Nine-foot Seam of Coalburn and Auchlochan contains a cannel-rib about 6 in. thick, yielding from 34 to 37 gallons of crude oil per ton. The Six-foot Seam of the same district contains a cannel of about the same thickness, with a yield of 52 gallons of oil, and the Big Drum Coal has a very irregular band varying in thickness from a few inches up to 2 ft. 6 in.

The cannels associated with blackband-ironstone need not be considered here, as they are thin and irregular, and the seams are, moreover, approaching exhaustion. Blackband-ironstone is now being wrought in Scotland only on a very small scale.

In the Upper Limestone Group, the Climpy Gas Coal is exhausted, but there are probably some reserves of the Ponfeigh Gas Coal, which is a compound seam containing up to 1 ft. 8 in. of cannel. An analysis for gas-making purposes showed 53·81% of volatile matter.

The Kiltongue Musselband Shale and Ironstone has been worked at a few localities for oil, and has been tried as a possible iron-ore. It occurs over the whole of the Central Coalfield, and shows typically:—

Dark parroty blaes	1 ft. 6 ins.
Tough shale or cannel	4–9 ins.
Shale with "mussels," often irony	8 ins.
Ironstone	2 ins.
Fireclay or blaes	

The yield of oil was between 30 and 50 gallons per ton. The associated iron-ore has been proved to be of very inferior quality.

The Craw or Gas coal of the Falkirk Coalfield is a compound seam of gas-coal and ironstone. At Crosscroes the gas-coal portion is 8 in. thick. The shale above the Virtuewell Coal was also among the materials used for distillation. It has been known to reach a foot or more in thickness, though it seldom exceeded 6 in. It was rich, yielding up to 72 gallons of oil, but is now practically worked out.

The Splint Coal characteristically contains a band of gas-coal of variable thickness, oscillating between 4 in. and 1 ft. It used to be distilled, and the yield was about 32 gallons per ton. The seam is now approaching exhaustion.

One of the Douglas Coal Measure seams contains at places a cannel up to about 2 ft. 3 in. thick, which in a distillation-test has yielded 47·1 gallons of crude oil per ton.

AYRSHIRE.

Cannels for gas-making purposes have been extensively worked in this coalfield. On a smaller scale they have been mined for oil-making. There have been few recent developments, consequently a large part of the present account is based on information already published mainly in Mr. R. W. Dron's 'Coal Fields of Scotland' and among the valuable analyses of Mr. G. R. Hislop.

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Carboniferous Limestone.—At Glenbuck, near Muirkirk, the Three-foot Seam and the Nine-foot Seam contain a band of gas-coal 5 and 11 in. thick respectively, which have been worked for gas-making.

Another gas-coal, 7 in. thick, and stated to be very rich, occurs 6 fathoms above the Three-foot Seam.

At Guelt, N.E. of New Cumnock, a gas-coal, known as the Clay Gas Coal, is reported to have been 1 ft. 8 in. thick. A gas-coal, 1 to 6 in. thick, worked long ago at Dalgain Pit, ½ mile N. of Sorn, may correspond with the Clay Gas Coal.

Cannel from one of the Dailly coal seams gave 46 gallons of crude oil in a distillation-test.

At Kilbirnie the 'Wee Coal' is a gas-coal, and is now worked out. A gas-coal about 12 in. thick was also found near Barmill. The cannel-coal of Wardend Colliery, near Kilmaurs, yields from 39 to 53·7 gallons of crude oil per ton. Oil-works for its distillation were being erected when the war broke out.

Coal Measures.—At New Cumnock two cannel-seams have been known for a long time and have been extensively wrought. Various names have been applied to them: Upper and Lower Gas Coals, Lanemark Cannel, Bank Cannel, Mansfield Cannel, Pathhead Shale and South Boig Shale. Mr. R. W. Dron[1] states that an intermediate seam, not yet wrought, has been found to reach at places a thickness of 24 in.

In the North Ayrshire Coalfield, cannel was retorted at Fergushill, N.W. of Kilmarnock, from 1864 to 1878, and also at the Craigie and Hurlford Oil Works, Kilmarnock, between 1864 and 1876. Remarks attached to Mr. G. R. Hislop's analyses show that the Fergushill 'Shale' was 6 in. thick and contained 31·04% of volatile matter. The Fergushill 'Cannel' was 9 in. thick, with 37·67% of volatile matter.

The cannel raised at Auchenharvie Colliery was 7½ in. thick, with 34% of volatile matter. The Bourtreehill Cannel was 6 in. thick, with 38% of volatile matter, the Caprington Cannel was 10 in. thick, with 37·4% of volatile matter, and the Eglinton Park Cannel, 6 in. thick, contained 39·22% of volatile matter.

In the area around Kilmarnock a parrot coal, between 1 and 2 ft. thick, occurs a few fathoms above the Hurlford Main Coal; analysis shows 24% of volatile matter. Locally, at Galston, the Linnbed and the Major Seams contain cannel-ribs with 34% of volatile matter. The shale on top of the Tourha Coal has given 14% of volatile matter on analysis.

ARGYLLSHIRE.

The small Campbeltown coalfield contains a compound seam of cannel and coal, some 40 fathoms below the Index Limestone. The thickness of the cannel portion reaches up to 20 or 25 in. The top portion yields up to 36 gallons of crude oil per ton, and the bottom part 27 gallons. It has been worked to some extent in the past, but is not wrought at present. The field has not been proved sufficiently to show whether the seam preserves its character throughout, but it possibly extends over an area of two or three square miles.

[1] *Op. cit.*

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LEAD AND ZINC IN SCOTLAND.

During the past year an investigation into the lead- and zinc-resources of Scotland has been conducted by Mr. Wilson, and in the course of the work the more important mining-districts have been visited. The results tend to show that, whilst some of the districts such as Leadhills, Wanlockhead, Newton Stewart, Tyndrum and Strontian may under favourable conditions be capable of further development, most of the others are either too remote or the veins too poor and few, to warrant exploitation under present circumstances. Previously to the war Leadhills and Wanlockhead were the only working lead-mines in Scotland, but the increased price of lead and zinc, and the scarcity of tonnage, resulted in the opening-up of old mines near Newton Stewart and Tyndrum, and of a small new mine at Achanarras in Caithness.

The average yearly output for the 10 years previous to the war was about 3,550 tons of galena and about 280 tons of zinc-blende. From 1914-1918 the annual output has risen to 4,340 tons lead-ore and 1,250 tons zinc-ore, the increase being due partly to the opening up of old or new mines, but mainly to increased production from the Leadhills and Wanlockhead districts.

Leadhills and Wanlockhead.—These two adjoining districts contain by far the most productive lead-mines in Scotland. The mines have been worked spasmodically since very early times, but for 250 years have practically been in continuous operation and must have produced upwards of 500,000 tons of lead-ore.

The rocks of the area are of Ordovician age, and the general succession is as follows:—

Caradoc	...	Lowther Group	1,000 ft.
Llandeilo	...	Lower Hartfell Shales Glenkiln Shales .	... 40–50 ft.
		Radiolarian Cherts	60–70 ft.
Arenig ...	...	Volcanic and Intrusive rocks (thickness unknown)	

The metalliferous portions of the veins are usually associated with the Lowther Group which, consisting mainly of hard, calcareous shales and greywackes, give rise on fracture to open fissures suitable for infilling by ore-bearing solutions. The productive veins are arranged along a N.E. and S.W. axis and occur within a lens-shaped area about 14 miles long by 4 or 5 miles in width.

The veins can be divided into two intersecting main sets. The trend of one set varies about 45° on either side of north and that of the other from W.N.W. to N.W. Little evidence exists as to the relative ages of the two sets, but such as there is points to the W.N.W. set being the older.

About 70 veins are known, and lead-ore has at some time or other been produced from practically all of them. At present, however, only four are being worked—namely, the New Glencrieff and its west branch, 'The West Grove,' at Wanlockhead, and Brow and Brown's Veins at Leadhills. The workings at both localities are extensive and have reached a depth of about 240 fms. The veins, whose walls are well defined, vary from mere strings to 16 or 18 ft. in width, and are usually filled with a breccia of greywacke-fragments, cemented by a calcite-matrix often containing interspersed galena. The whole is also cut by

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numerous vertical strings of galena varying from ½ in. to 3 or 4 ft. in thickness, and in exceptional cases from 12-14 ft. of solid galena has been seen. At the present time the average values of the slopes are about 10 cwt. to 1 ton of ore per fathom at Wanlockhead, and 1 to 2 tons per fathom at Leadhills.

The primary minerals of the veins are galena, jamesonite, zinc-blende, pyrites and chalcopyrite. Of these galena only is worked at Leadhills, but at Wanlockhead blende also has been extracted since 1870. About the middle of the 18th century one or two veins were worked for copper-ores.

The common gangue-minerals are calcite, dolomite, quartz and barytes, but none occurs in sufficient quantity to pay for extraction. A cavity recently opened at the 200 fm. level in the West Branch of the New Glencrieff Vein yielded the first authentic specimen of Scottish witherite. The mineral occurred in beautiful radiating masses which are evidently secondary after barytes.

The veins are exceedingly rich in secondary minerals, due to oxidation of the primary sulphide ores. Several of the rarer species, such as leadhillite, caledonite and lanarkite, were first recorded from the district.

Newton Stewart.—A large number of mineral veins carrying lead-, zinc-, and copper-ores occurs around the Cairnsmore Granite mass. Blackcraig Vein was accidentally discovered in 1763 during the making of the Military Road, and, soon after, the mine was opened up and the ore shipped to Chester for smelting. During the recent visit to the localities, it was found that at Wood of Cree, now being opened up and worked, an interesting view of the vein can be obtained. The walls are ill defined, and the country-rock for a few yards on either side is impregnated and strung with thin veinlets of ore. In addition there occurs near the centre of the vein a definite brecciated zone containing strings of galena and blende ranging up to 4 in. in thickness. Many of the veins of the district are of this composite type, and at Blackcraig the 'bearing ground,' as the impregnated country-rock is called, attains in places a width of about 20 yards.

Tyndrum.—The veins of this district were accidentally discovered in 1741 by Sir Robert Clifton who at that time held the mining lease of the Breadalbane property. He opened up the mine and raised 1,697 tons of lead-ore between 1741 and 1745. From that time to 1768 the mine passed through various hands, and in all about 3,318 tons of ore were raised. In 1768 the Scots Mining Co. obtained a lease, erected a smelting-mill about 1 mile east of the mine, and between 1768 and 1790 produced 1,678 tons of lead from 3,683 tons of ore. After 1790 work was only carried on intermittently till 1858 when the late Marquis of Breadalbane took the mines into his own hands. From 50 to 100 tons of ore were raised annually till his death in 1862, when work ceased. In 1917 the mines were taken over by the Tyndrum Mines, Ltd., and are now being opened up.

This district is situated in an area of metamorphic rocks consisting mainly of mica-schists, quartzites and quartzose-flags with occasional interbedded schistose bands. A large N.E. fault, throwing down to the S.E., crosses the area, and, as will be seen from

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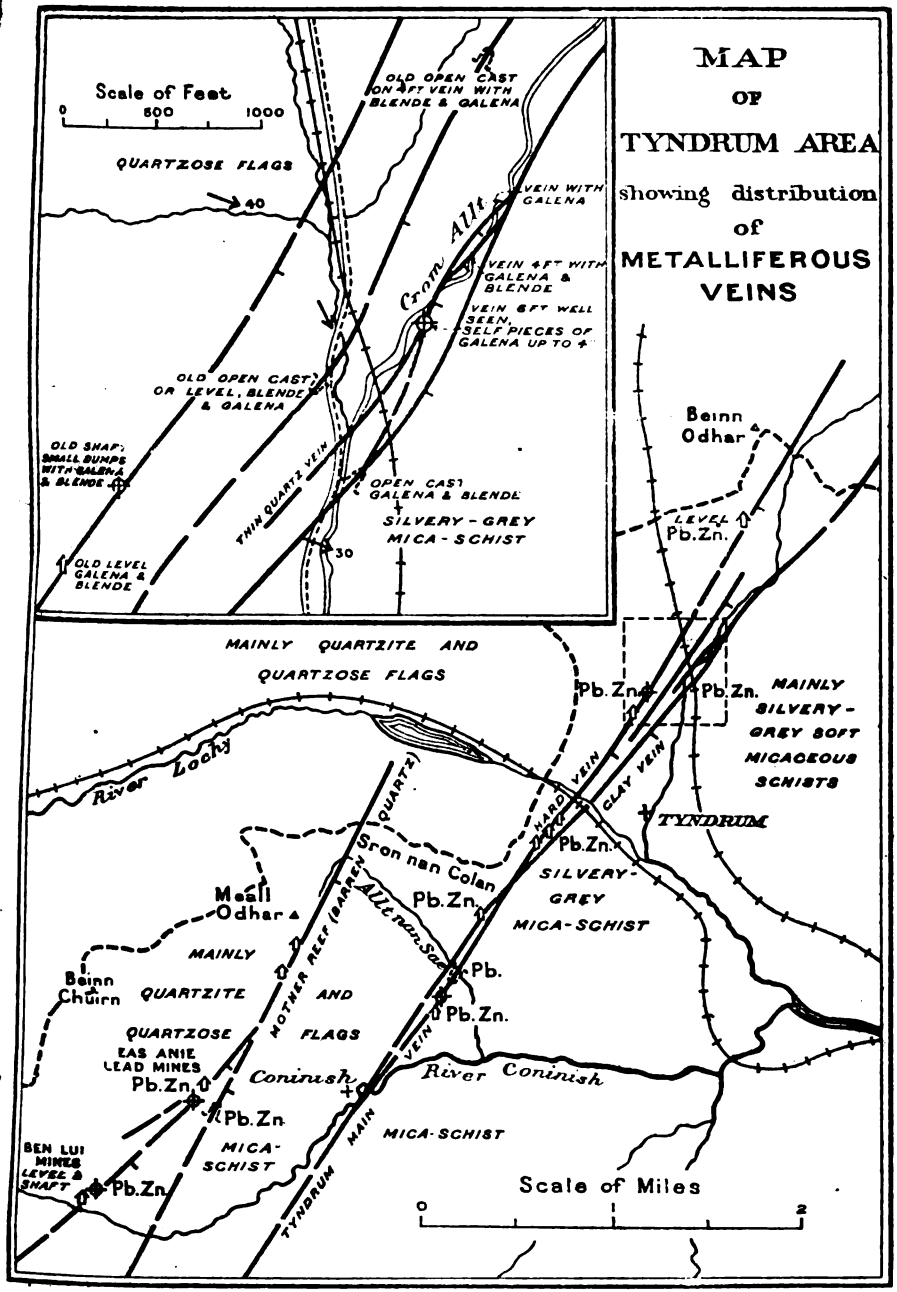
Fig. 1.



The inset map represents the small area indicated to the north of Tyndrum on a larger scale.

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the map, Fig 1, the metalliferous veins are situated along this fault, and also parallel to it in the area of quartzose rocks occurring on the N.W.

At the Tyndrum Mines two veins were worked, the Hard Vein and the Clay Vein, the latter being a metalliferous portion of the main fault. The ground between them is not disturbed to any extent. Farther to the S.W. the veins become known as the 'Tyndrum Main Vein,' and where they cross the Allt-nan-Sae they are about 100 yards apart, the rock between them being much shattered and strung with thin quartz veins. The vein on the north boundary of this shatter-zone contains a little iron-pyrites only, but that to the south contains also galena and blende. About a quarter of a mile farther south an old level, driven in a N.W. direction, appears to have cut the southern limb of the vein, which, judged by the material in the dump, contained a fair quantity of complex lead- and zinc-ores. Farther south again, where it crosses the Coninish River the vein has recently been opened and found to contain a fair quantity of galena. When traced north from Tyndrum the veins are not seen till they cross the Crom Allt about 1 mile from Tyndrum. Here the Clay Vein has been worked opencast a short distance on the N.E. side of the burn, near the road. About a quarter of a mile farther up the burn, however, the fault (Clay Vein) can be seen to contain no ore. Two small offshoots, both of which are metalliferous, cross the burn from the west side, and are cut off against the fault. About 200 yards southwards they apparently join, and the conjoint vein is well seen crossing the burn about 100 yards upstream from the railway bridge. The southwards extension is nowhere visible, but it probably joins with the Clay Vein near the point where that vein is metalliferous, at the small open-cast already mentioned.

The Hard Vein can be traced from Tyndrum to near the top of Beinn Odhar, where it was at one time worked opencast and by level. A little galena and blende can still be found on the dumps. An old shaft and a level about a quarter of a mile west of the Crom Allt railway-bridge, are also probably on the course of the Hard Vein. About half way between the two main veins, another vein can be traced by trials, and an old level from the road-side near the railway-bridge to a point about $\frac{1}{4}$ mile away up the side of Beinn Odhar. It is about 4 ft. wide and contains a fair quantity of blende and galena.

Ben Lui and Coninish Mines.—A barren quartz-reef, known as the Mother Reef, is shown on the map (Fig. 1), running in a N.E. direction from the Eas Anie to Meall Odhar. About $\frac{1}{3}$ mile N.E. of Eas Anie it appears to branch, and from this point southwards becomes metalliferous. The westerly branch or branches have been worked at Eas Anie and at Ben Lui. At the former place the levels on the more westerly branch are open, and galena and blende associated with barytes can be seen. At Ben Lui the same minerals occur on the dumps at the mouth of the level.

The easterly branch, which keeps the same trend as the Mother Reef, is visible at a trial on the hillside about a quarter of a mile S.E. from Eas Anie and there shows a fair quantity of blende and galena.

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The veins contain a complex ore scattered through a quartz-gangue. The galena and blende are usually, however, in small pieces and intimately mixed, so that it has been impossible to separate them, but with improved plant this may be possible. The old dumps at the Tyndrum Mines are estimated to contain about 40,000 tons of material yielding approximately 9·5% of lead and 6·5% of zinc.

Strontian.—These mines and those of Lurga in Morvern are believed to have been discovered by Sir Alexander Murray, of Stanhope, in the early part of the 18th century. He was the proprietor of Strontian and appears to have leased the mines to the Duke of Norfolk, who afterwards made them over to the York Buildings Co. The Lurga Mines were leased from the proprietor, the Duke of Argyll, and in a statement made by Duncan Forbes, of Culloden, to the Duke of Argyll in 1737 we find that the rent paid was £41 17s. 7½d. In 1733 an interesting map and account of the area was published under the title, 'A Plan of Loch Sunart.'

The Strontian Mines were worked continuously till 1815, but since that time the workings have been intermittent and on no great scale. In 1809 the output seems to have been about 400 tons of lead per annum, but it gradually fell away, and when work ceased in 1871 it was only 9 tons.

The country-rock varies from hard mica-schist, with banded quartzites in the west near Coire-an-t-suidhe, to augen-gneiss at Fee Donald in the east.

The veins, several of which have been worked, all have a trend of about 5° N. of W., and except at Coire-an-t-suidhe are associated in each case with a highly-decomposed basalt dyke.

The primary ores are galena, jamesonite and zinc blende with a little pyrites. Galena has been worked extensively at Strontian (Whitesmith and Bellsgrove Mines); at Coire-an-t-suidhe 30 tons of blende also were extracted in 1871. The gangue consists mainly of barytes and calcite, occasionally with small quantities of strontium-minerals such as strontianite and celestine.

The Lurga vein is situated in Glen Dubh on the estate of Laudale and about 3 miles south of Laudale House, on the south side of Loch Sunart. It is of the same type as the Strontian veins and like them is accompanied by a decomposed basalt dyke. The ores are mainly galena and blende associated with white barytes and quartz, and at one part the vein shows about 4 ft. of fairly clean barytes.

The Strontian veins have been worked to a depth of over 100 fms., but the workings are now full of water to adit-level.

The Coire-an-t-suidhe vein, which is visible at several places, contains a fair quantity of galena, perhaps 10 cwt. per fathom, together with blende up to 1 ft. or 18 in. thick still remaining on the footwall of some of the opencast workings. The higher workings are full of water, from which it may be inferred that the vein is water-tight, and that the low level cannot have been driven far into the hill.

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BAUXITIC FIRECLAY IN SCOTLAND.

Much interest having been aroused in the Ayrshire Bauxitic Clay as a promising refractory material, this opportunity is taken of giving a brief account of its character and origin, and a history of its discovery.

The clay is of Millstone Grit age and the general sequence of that series in North Ayrshire is as follows:—

Saltcoats bauxitic clay	6–24 ft.
A series of lava-flows with interbedded foul coal, fireclays and ganisters	6–40 fms.
Monkcastle clay	10–20 ft.
Sandstone	20 ft.

It will be seen that the sequence consists mainly of igneous rocks with fireclay-deposits both above and below, but whereas the lower fireclay seam is simply a high-grade clay of the ordinary type, the upper seam has properties such as hardness, conchoidal fracture, oolitic structure, and high percentage of alumina, which are not found in ordinary fireclays, but more nearly resemble those of bauxite. On the other hand, bauxites contain a large amount of free alumina soluble in hydrochloric acid; while in this deposit the bulk of the alumina is combined with silica in the form of some mineral after the nature of kaolin, and the excess alumina is not to any great extent soluble in acid. The occurrence of the deposit at the top of a series of basalt lava-flows, and its intimate association with beds rich in iron and resembling laterites, suggest that the origin was in many respects similar to that of bauxite, but whereas that material is an exceedingly porous rock the Saltcoats bauxitic clay is compact, and only slightly porous. This difference suggests that the rock, though originally deposited as a normal bauxite, has undergone silicification, but the possibility of its having been originally deposited in its present form is not excluded.

Mr. John Smith, of Dalry, was probably the first to recognise the lateritic origin of the ironstone-seams that occur at the top of the Millstone Grit Series in Ayrshire, and an attempt was made to work them for iron-ore at an exposure on the Lugton Water, near Sevenacres Mill. It was not, however, till the recent revision of the area by the Geological Survey that the bauxitic character of some of the beds attracted attention. Two samples were analysed, and of these one, collected by Mr. E. M. Anderson from the outcrop on Saltcoats shore, yielded 47·7% of alumina. This result was communicated to Mr. W. Douglas, of Kilwinning, who was then working the Monkcastle Clay. He submitted further samples to Dr. Mellor, of Stoke-on-Trent, who reported a refractory quality of over Seger Cone 35.

At that time the late Dr. C. T. Clough was engaged in mapping the Kilmarnock district, where also both of the fireclay horizons are represented. He had samples collected from above and below the Millstone Grit lavas and provided the funds for the conducting of a series of refractory, shrinkage and porosity tests by Dr. Mellor. The results were disappointing, for from neither horizon was the clay nearly so refractory as that of the same bed in the west.

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The occurrence of this bauxitic clay was made known to a number of people who were inquiring as to the sources of refractory and other materials, but the first to take leases of the ground and to work the clay were Messrs. Adamsez, Ltd., of Scotswood-on-Tyne. The results obtained by its use were so satisfactory that other firms became interested, and several other areas were taken up. Among the special properties which attracted attention, mention may be made of its high resistance to heat and its suitability for those portions of furnaces which are exposed to the highest temperatures, such as the gas-ports of glass-furnaces. It has also proved specially useful for electric steel-furnaces. Probably on account of its hardness and its non-plastic nature, alone it is not easily made into bricks and other shapes, but means have been found of overcoming this difficulty, and many forms of fireclay goods made from it are now on the market. It seems likely that this clay, and other similar clays, if they can be found, will fill a definite place in the British refractories industry.

The Millstone Grit Lava Series has been recognised over a great part of North Ayrshire, and in the Island of Arran. The main outcrop has been traced from Saltcoats shore to the Fenwick Water, near Kilmarnock, and north of it a few outliers have been located to the north of the Dusk Water fault, as, for instance, the strip running from the Glenburn to Monkcastle and that from Blair to near Giffen House. Southwards from the main outcrop the presence of the bauxitic clay is not yet fully proved. Since the lavas are again found outcropping to the south of the Galston-Dundonald fault, and the bauxitic clay has been recognised in some of the bores along the northern edge of the Mauchline basin, it seems that the deposit may underlie the whole of the North Ayrshire Coal Measures, though the possibility of its having been eroded locally before the deposition of the Coal Measures must not be overlooked. Its extension into the South Ayrshire Coalfield has not been proved. The presence, however, of detrital deposits of the same nature at Sanquhar and Stranraer warrant the hope that it may exist in the Ayr, Dalmellington and Cumnock districts.

The presence of the seam in Arran proves its wide westward extent and suggests its probable occurrence under the Firth of Clyde, where Coal Measure seams have already been worked from Stevenston and Saltcoats. Several of these workings are, however, now full of water.

The bauxitic clay is usually of a pale-grey to buff colour, but reddish, green, mottled, and even black varieties are common. The hardness varies from that of a hard limestone to a limey blaes or marl. The fracture is conchoidal and innumerable joint-planes cause the material to weather down in a debris of small cubic or rectangular blocks.

The rock is fine, even-grained in texture and often contains numerous rootlets; in other parts the texture is distinctly oolitic and these oolitic varieties are the richest in alumina. In both of these types the original structure has almost entirely disappeared, but in some beds it can still be made out. In many cases the parent-rock has been a volcanic ash and in others a lava, for

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it shows the remains of what appear to have been amygdules. The seam, though remarkably persistent, varies in thickness, character and chemical composition. At Saltcoats the section exposed shows about 11 ft., composed of the following beds:—

	Ft.	In.
Fine-grained grey clay with rootlets	2	6
Dirty coal	2	–
Black clay	2	3
Hard grey clay with angular fragments (volcanic ash) ...	1	6
Black clay	–	4
Fine-grained grey clay with rootlets	1	4
Hard grey oolitic clay	1	3

At the exposure on the Lugton Water, near Sevenacres, the section is as follows:—

	Ft.	In.
Pale buff-coloured fine-grained homogeneous clay with rootlets	3	–
Pale-grey clay weathering spheroidally	3	–

The exposure in the Annick Water gives the following section:—

	Ft.	In.
Hard white clay...	2	6
Ironstone rib (decomposed basalt)	2	6
Hard white clay...	2	3
Black speckled clay passing down into altered volcanic ash	1	2
Irony rib	–	2
Hard white clay passing down gradually into decomposed lava	2	6

The chemical composition of the deposit is not uniform and the constituents vary as follows:—Al_2O_3, 26-50%; SiO_2, 28-50%; Fe_2O_3, less than 1-8%, TiO_2, 2-14%, combined water 7·5-15%. In composition, therefore, the deposit varies from a normal fireclay to a siliceous bauxite, but mineralogically it differs from a bauxite in that the alumina is not in a free state, soluble in hydrochloric acid. In many of the samples examined some, if not all, of the titanium is in the state of rutile (TiO_2), which is an exceedingly stable substance but considerably reduces the refractory quality of the clay when present in a proportion of more than 5%. The iron may be present either as small specks of the carbonate (sphaerosiderite) or as pyrites. The refractory quality of the clay is also exceedingly variable, ranging from Seger Cone 38 for the best oolitic material to Cone 29 for the inferior types. From the evidence as yet to hand, the lenticular pockets of high-grade material seem to be better developed at the Saltcoats end of the field, but there appears to be no reason why they should be thus restricted.

REVISION OF PARTS OF BANFFSHIRE AND ABERDEENSHIRE.

The districts around Portsoy, Banff, Boyndie and Cornhill in Sheet 96, and around Glenbarry, Rothiemay, Huntly, Kennethmont, Insch, Rayne and Daviot in Sheet 86 have been mapped by Mr. Read. The area was originally mapped mostly on the 1" scale by Dr. Horne in 1881-4; the portion revised, which occupies some 200 square miles, is illustrated in Fig. 2.

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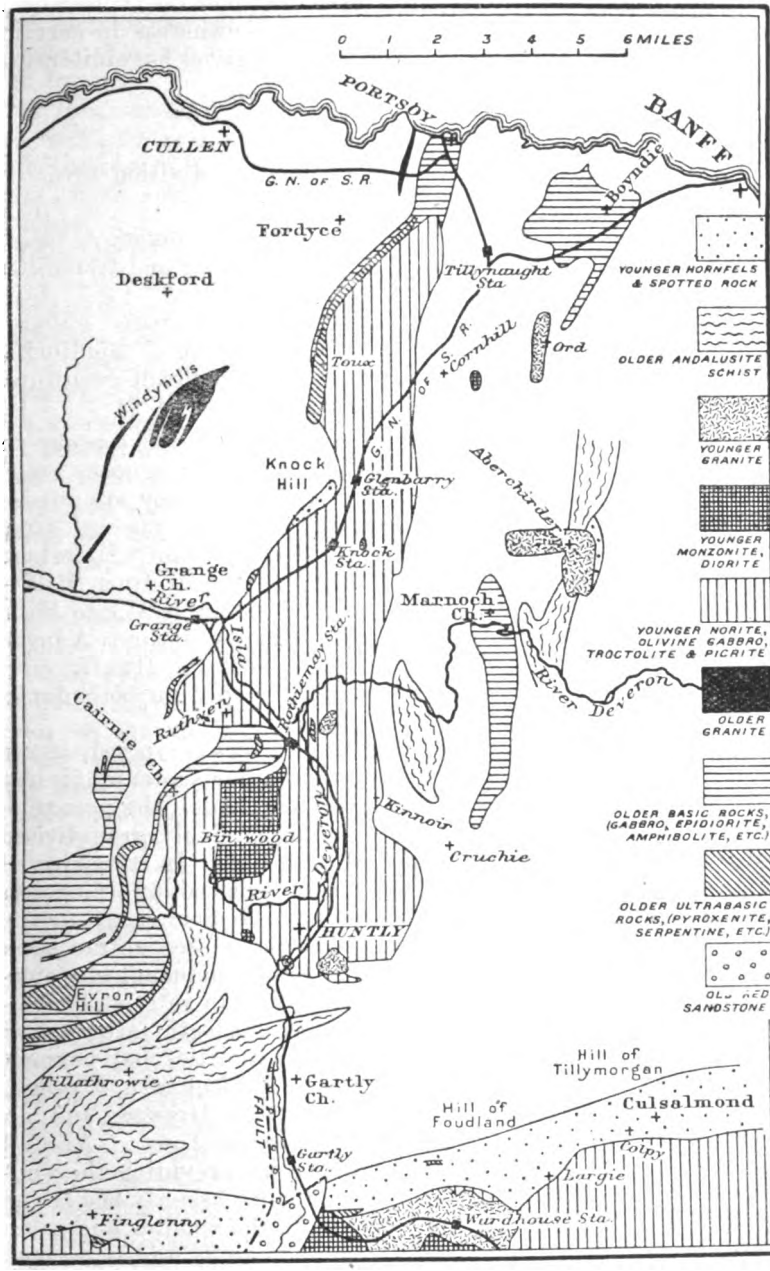

Fig. 2.—Sketch Map showing distribution of Igneous Rocks, Contact-rocks and Older Andalusite Schist in Strathbogie and Lower Banffshire.

The igneous rocks are separable into two classes: an Older Series—intruded largely prior to the movements which caused the present disposition and foliation of the schistose rocks, and a Younger Series—intruded after those movements. The thermally

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metamorphosed rocks produced by the intrusion of the Older Series have been foliated by the later movements, whereas in certain places contact metamorphism by the Younger Series has obliterated the older foliation of the country rocks.

THE OLDER IGNEOUS ROCKS.

The Older Igneous Rocks are capable of division into the following classes:—

(1) *Ultrabasic.*—Olivine rocks, olivine-pyroxene rocks, pyroxene rocks, with derived serpentinous and tremolitic rocks.

(2) *Basic.*—Labradorite rock, gabbro, enstatite gabbro, diorite, with derived hornblende gabbro, epidiorite, amphibolite, hornblende schist and hornblende granulite.

(3) *Acid.*—Granites with derived augen gneisses.

1. *Ultrabasic Older Igneous Rocks.*—These rocks occur in general intimately associated with the basic older igneous rocks and are probably the oldest of this series, since they are cut by thin epidiorite dykes. They form long sill-like masses, most of which, but not all, occur about one horizon east of a limestone which is east of the quartzite forming the ridge of Durn Hill—Knock Hill—the Balloch. Smaller lenses occur at White Hill, Mortlach and Avochie Castle, around Rothiemay Station. A large mass shows at Hill of Milleath, 4 miles west of Huntly, and ultrabasic older igneous rocks are well developed on both flanks of Evron Hill and Brown Hill of Glass.

The predominant type of this division is a rock composed almost entirely of augite, with subordinate and rather sporadic olivine. As seen at White Hill, in a rock crushed when solid, the pyroxene occurs as large angular plates in a matrix of finely granulitised augite of a character similar to that of the plates. In more altered specimens, the granulitised pyroxene is replaced by colourless tremolite blades and greenish serpentine; the final stage in the alteration is exemplified by a rock composed of serpentine, iron oxides, and large blades of tremolite. The development of tremolite and the degree of crushing of the rock are intimately connected. Similar rocks are seen at Hill of Milleath, Hillside of Glass and Craigs of Succoth. Among other varieties may be mentioned a pyroxene serpentine occurring at Ballochburn, Grange, a slaty foliated serpentine at Drumnagaroch, Grange, and an olivine hypersthene hornblende rock at Meikle Toux. Around Portsoy, several crops of ultrabasic type occur, providing the well-known 'Portsoy Marble.' The larger and more westerly bed to the west of the town is an olivine serpentine, the smaller and more easterly bed shows tremolite, pyroxene and calcite and is derived from a pyroxene rock. The serpentine of the Burn of Durn below Aird Bridge, Portsoy, contains abundant bastite and is associated with enstatite gabbro. Several small bosses of serpentine occur at East Head, east of Portsoy.

In conclusion, therefore, it may be stated that the original rock of the majority of the ultrabasic older igneous rocks of this area was one composed largely of pyroxene, in most cases augite, more rarely a rhombic pyroxene; olivine occurs in subordinate amount,

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although it may be locally abundant. The whole series is much altered with the production of serpentine and tremolite, the formation of which has been aided by the development of crushing and foliation.

2. *Basic Older Igneous Rocks.*—The basic older igneous rocks are well seen at Portsoy, around Boyndie, south of Ruthven and on both sides of the Deveron west of Huntly. A detached sill-like mass runs north and south from Marnoch Church nearly to Cruchie.

This series of rocks is much altered both structurally and mineralogically, but it has been possible to delineate the sequence of the alteration by the examination of a large number of thin sections. The least altered type is seen at Portsoy. This rock, a true *gabbro,* consists of labradorite and large ophitic plates of augite, marginally altered to brownish-green hornblende. Biotite, iron oxides and apatite complete the rock. Locally enstatite may be present in addition to the monoclinic pyroxene. More acid bands occur in these gabbros characterised by the presence of quartz and a medium plagioclase. The second stage in the alteration is marked by the complete disappearance of the pyroxene, whose place is now taken by aggregated prisms or compact plates of secondary hornblende. At the same time the turbid original plagioclases show within them a few clear grains of secondary felspar. This rock, which is not structurally altered, may be called an *epidiorite.* The third stage in the alteration is characterised by the growth of innumerable needles and prisms of hornblende at the edges of the secondary hornblende plates. The felspar becomes filled with these wandering prisms and, at the same time, it is replaced by a mosaic of grains of clear felspar usually of more acid composition. The iron oxide has mostly gone over into leucoxene; epidote occasionally occurs. This is the *amphibolite* type, in which hornblende is largely in excess of felspar, but it should be noted that no schistose structures have been developed.

With the development of schistose structures a second series may be produced. The first type is a *gabbro schist,* in which hornblende and labradorite are arranged in parallel bands. The amphibole is secondary from pyroxene, but most of the plagioclase is original, although granulitisation is sometimes well developed. A further stage produces a true *hornblende schist* with hornblende in excess of the felspar, well-marked schistose structure and complete granulitisation and recrystallisation of the felspar; the final stage produces a *hornblende granulite* in which felspar and hornblende (with some biotite) are associated in rounded grains. All these types may be found at Portsoy.

The complete failure of ferromagnesian minerals (perhaps related to the complete failure of felspar in the neighbouring pyroxene-rock) has produced at Portsoy a rock composed wholly of labradorite felspar, approximating in character to the anorthosite of Canada.

To summarise the investigations on the basic older igneous rocks it can be said that the original rock was a pyroxene-labradorite rock or gabbro. By the amphibolisation of the pyroxene is pro-

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duced first the epidiorite type; by the growth of secondary hornblende in the felspar together with concomitant production of secondary felspar in granules, an amphibolite is formed. Movement has produced the types of gabbro schist, hornblende schist and hornblende granulite.

3. *Acid Older Igneous Rocks.*—Older igneous rocks of acid composition occur at two localities. One mile west of Portsoy an augen gneiss forms a narrow lens in the schists. In this rock, large eyes of microcline, orthoclase and subordinate oligoclase are set in a cataclastic ground mass of granular quartz and felspar with shreds of primary biotite; much secondary muscovite occurs along shear planes.

The second area of foliated granite is around Windyhills. The rock shows large phacoids of pinkish felspar separated by flaser of greenish and silvery micas. This foliated variety passes into a coarse-grained porphyritic non-foliated granite.

THE YOUNGER IGNEOUS ROCKS.

The younger igneous rocks are remarkable for their variety, extent and contact effects. They form a broad belt stretching from Huntly northwards to within two miles of Portsoy; this may be called the *Huntly Mass.* The northern part of a second belt is found on the southern edge of Sheet 86 and may be called the *Insch Mass.* Isolated granite bosses occur at Aberchirder, Ord and Longmanhill (4 miles E.S.E. of Banff).

(*a*) *Huntly Mass.*—The following scheme shows the classification of the Younger Igneous Rocks of the Huntly Mass, and their relative ages, beginning with the oldest:—

1. *Picrite-Norite Set.*—Picrite, Olivine Gabbro, Troctolite, Norite.
2. *Diorite.* (Gibstone).
3. *Monzonite and Diorite.*
4. *Granite.*
5. *Tourmaline Pegmatites.*

These rocks are best exposed in the district around Huntly and have been described for that area by W. R. Watt,[1] on whose work the following description, in so far as it applies to the Huntly district, is of necessity largely founded.

1. *Picrite-Norite Set.*—This composite intrusion is best displayed to the west of Huntly. Its members are picrite (olivine, augite, little felspar), olivine gabbro (olivine, augite, plagioclase), troctolite (olivine, labradorite), and norite (hypersthene, augite, labradorite). These members occur from west to east in the order given, the picrite forming a rather narrow border to the mass, followed eastwards by a small development of olivine gabbro and this again by more widespread troctolite. All these types occur in the western parts of the Bin Wood and Dunbennan Hill. The norite is the most widely developed forming the main parts of the intrusion, and related types extend northwards from Huntly nearly to Portsoy. Troctolite and picrite occur in the railway cutting

[1] W. R. Watt. "The Geology of the Country around Huntly (Aberdeenshire). *Quart. Journ. Geol. Soc.*, 1914, pp. 266–293.

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at Rothiemay Station, and troctolite also occurs west of the norite between Grange and Knock Stations. It seems probable that the Picrite-Norite Set were intruded into one another whilst they were all fluid after a period of differentiation in a lower magma.

2. *Diorite.* (Gibstone).—A small knoll of foliated diorite (quartz, biotite, augite, andesine) occurs near Gibstone (1½ miles north-west of Huntly) in an area of unfoliated norite. It is intermediate in composition between the norite and the later monzonite, and its foliated character may be explained by its being still hot and soft at the time of the movements which caused the monzonite to present a markedly intrusive character towards the norite. An allied type, but unfoliated, occurs at Craigwillie, 1 mile west of Huntly.

3. *Monzonite and Diorite.*—Intrusive into the already solid picrite-norite set are the Bin Wood monzonite and associated Cormalet mica diorite. These rocks were called by W. R. Watt the *Central Intrusion.* The monzonite consists of orthoclase, plagioclase, augite, biotite, quartz and widespread garnet. Its contact effects on the neighbouring norite will be described later.

4. *Granite.*—Granite (quartz, orthoclase, microcline, plagioclase, biotite and muscovite) occurs in several small masses, but is quite subordinate in amount to the more basic igneous rocks of this period. At Carvichen (1 mile S.E. of Huntly) the granite is marginal to the norite; at Rothiemay (Avochie) and Ternemny (Knock Stat.) the granite masses are surrounded by norite. The granites of Aberchirder, Ord and Longmanhill occur, unassociated with more basic members, in the metamorphic rocks.

5. *Pegmatites.*—Numerous pegmatites with tourmaline penetrate the norite and the neighbouring schists.

(*b*) *Insch Mass.*—The microscopic investigation of the rocks of this Mass has not yet been carried far enough to permit of a detailed description.

The northern part of the Insch Mass occurs along the southern margin of Sheet 86. In the parish of Rhynie, south of Finglenny, a beautiful olivine norite occurs, composed of labradorite, olivine, hypersthene, biotite, augite and magnetite. The sinuosities of the crop of this rock have permitted some thin sill-like masses of basic and ultra-basic rock, referable to the Older Igneous Series, to peer out in detached areas.

In the Kennethmont and Wardhouse districts, Younger Igneous Rocks of various types are developed, as shown on the sketch map. Some of the rock is similar to that just described. Other varieties are more acid and approach diorite. The pink coarse-grained rock occurring around Wardhouse is found to consist of microcline, oligoclase, biotite, hornblende and a little quartz. The noritic type extends, so far as can be estimated from hand specimens, through the parishes of Insch, Culsalmond, Rayne and Daviot.

MODIFICATION OF YOUNGER IGNEOUS ROCKS BY INCORPORATION OF SEDIMENT.

Incorporation of sediment by the Younger Igneous rocks was postulated by W. R. Watt to explain the occurrence of cordierite

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norites at Wells of Cuternach, $3\frac{1}{4}$ miles W.N.W. of Huntly. During the course of the present survey, incorporation of sediment with the consequent production of abnormal rock types has been found to be extremely widespread. Marginal exposures of the norite show the rock crowded with partially digested fragments of the neighbouring schists, mostly phyllites. This is not confined only to the norite nor only to the margin, but interior exposures of both norite and monzonite show similar phenomena. By this solution of these sedimentary inclusions a new magma of abnormal character has been produced, a salient feature of which is the occurrence of cordierite, pleonaste, sillimanite, and garnet, accompanied by rearrangements of the original constituents of the igneous rocks. Such contaminations of the Younger Igneous Rocks by sediments are manifest in W. R. Watt's original locality—*i.e.*, Wells of Cuternach, and also near Ward (1 mile W.S.W. of Huntly), in the Deveron below Huntly Castle, in the Bin Wood, in Battlehill Quarry (Huntly), at the Hill of Kinnoir, near Rivestone ($1\frac{1}{2}$ miles east of Rothiemay Station), around Ruthven, on both sides of the Deveron at Rothiemay village, east of Wether Hill (1 mile S.E. of Glenbarry Station) and in Glen Barry. The effect of incorporation of sediment is always to produce an abnormal rock type.

CONTACT EFFECTS OF IGNEOUS ROCK ON IGNEOUS ROCK.

As described by W. R. Watt, cordierite norites have been produced from the ordinary norite at its contact with the later monzonite of the Bin Wood. These contact rocks are characterised by the presence of cordierite, spinel, sillimanite and, very rarely, corundum. The hypersthene of the norite is partially replaced by magnetite, garnet and biotite.

Acid pegmatites were credited by W. R. Watt with the production of similar effects, but, though this may be true for certain localities, it is probably not the case at Battlehill Quarry, Huntly. The usual and widespread alteration produced in the norite by pegmatites is the development of a 'dioritic' type, characterised by hornblende, biotite, labradorite, and more acid felspars. This rock is very like some of the epidiorite-amphibolites of the Older Igneous Series. At Keillenknowes (Ladysmith), 2 miles S.E. of Rothiemay Station, thin pegmatites in the norite have produced a remarkable rock composed of large plates of brown hornblende and biotite poikilitically enclosing small andesine grains.

The Older Igneous Rocks of gabbro facies have been contact altered by the Younger Igneous Rocks at Rothiemay and to the south of Finglenny, Rhynie, with the production of a garnet felspar hornblende pyroxene granulite resembling some of the Saxon granulites.

THE OLDER ANDALUSITE SCHISTS.

The distribution of the older andalusite schist is shown on the sketch map. In the main, this rock is a silvery phyllite with very thin lamination, studded with resistant knots and crystals of andalusite. Staurolite and cordierite also occur. Often the rock is more massive, but can everywhere be distinguished from the

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younger contact altered rocks. Its origin may be explained either by regional metamorphism, or by contact alteration produced by the Older Igneous Rocks. The examination of the coast section between Banff and Portsoy seems to indicate that it is of contact origin, but until the relations of similar rocks in the eastern part of Sheet 86 have been investigated it would be premature to dogmatise as to its origin. In places, however, as at Portsoy, andalusite-staurolite schists have been unquestionably produced by the Older Igneous Rocks. What may be stated with certainty is that the older andalusite schist existed as such before the foliation and before the intrusion of the Younger Igneous Rocks.

THE YOUNGER CONTACT ROCKS.

Along the border of the Insch Mass a belt from one to two miles wide of contact-altered rocks is found. The unaltered rock is a bluish slate with an excellent cleavage, formerly worked for roofing-slate west of Gartly Station and all along the slate ridge which runs from Gartly Station eastwards by Foudland Hill to the Hill of Tillymorgan. Passing southwards off the unaltered slates and towards the Younger Igneous Rock of the Insch Mass, the first evidences of contact action encountered are the development of small rod-like markings in the slate; the cleavage is still excellent. Proceeding still farther towards the Younger Igneous Rock, the cleavage in the sediments becomes totally destroyed and a light bluish massive rock with well developed dark circular spots is formed. These spots are of various origins, being due to the heaping together of dust-like iron oxides, to the development of platy micas and to the incipient crystallisation of andalusite and cordierite. Near the Younger Igneous Rocks a true hornfels is produced, giving a massive, very fined grained, dark rock, which in slice is seen to consist of cordierite, andalusite, sillimanite, micas and quartz, with typical hornfels appearance. The norite south of Finglenny seems to have metamorphosed the older andalusite schists on Cloichdubh Hill, and, by adding its effect to the older metamorphism, has produced a coarse rock with large biotites, muscovites, and cordierite together with water-clear pleochroic crystals of andalusite.

The Aberchirder and Longmanhill granites have produced spotting in the slates into which they were intruded.

The absence of any definite aureole around the Huntly Mass is probably due to the fact that this mass is intruded, especially in its northern part, into a series of sediments which had already been altered either regionally or by the intrusion of the Older Igneous Rocks. Nevertheless, near the margin of the Huntly Mass (as shown by W. R. Watt for the Huntly district) contact rocks are abundant. This hornfels shows much garnet, cordierite, sillimanite and biotite, and occurs at numerous localities both in the Huntly district and to the north. Specially beautiful examples may be found in the partially digested sedimentary lumps abounding in the monzonite and norite, and also at Cumrie (1 mile S.W. of Rothiemay Station) and at Loangarry (2½ miles E. of Huntly). North of the Huntly district similar types are met with around Rothiemay village, and an excellent garnetiferous hornfels occurs N.W. of Knock Station.

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III.—PETROGRAPHICAL WORK.

The work carried out in the Petrographical Department during the past year has been mainly the furnishing of reports on matters of economic and scientific importance to the Admiralty and other Government departments. Dr. Thomas, as technical adviser to the Admiralty in the selection of certain materials for the Anti-Submarine Division, has supervised and carried out the testing of the selected material. A mineral from a captured German cargo has been identified. Reports have also been furnished on the resources of zirconia, and on potash- and soda-bearing rocks in the North Wales District.

Dr. Thomas has investigated and determined the mode of construction of certain German-made Nicol prisms and has shown that effective prisms can be constructed with considerable economy in Iceland spar by adopting that mode. He has also carried out experiments with good results on the construction of combination glass- and spar-prisms, in the manufacture of which a still greater economy in Iceland spar may be effected.

Typical specimens of iron-ore from the Forest of Dean examined for Professor Sibly proved to consist mainly of the mineral goethite.

The special report on British Refractory Materials (Silica rocks and Dolomites) has been proceeded with.

IV.—CHEMICAL WORK.

For the 'Special Report' on British refractory materials 44 dolomites, obtained from quarries in various parts of the country where the material is worked, have been analysed.

The tabulation of the results of the analyses of silica-rocks, mentioned in the Summary of Progress for 1917, has been proceeded with.

The percentages of soda and potash in a fresh average sample of granite from Corrennie, Aberdeenshire, have been determined. A complete analysis of the rock is desired, and the results will be given later.

A waste-product from a colliery was tested to ascertain if it could be put to any commercial use.

A mineral, taken from a captured German cargo was analysed and a report upon it was drawn up in collaboration with Dr. Thomas.

V.—PALÆONTOLOGICAL WORK.

England and Wales.

Collections of fossils obtained by Mr. Pringle from boreholes at Kimmeridge, Corton and Donnington-on-Bain have thrown further light on the zonal palæontology of the Kimmeridge Clay.

Numerous additional fossils have been arranged by Mr. Allen in the Museum-cases, including a series of types and other examples of graptolite-species illustrating papers by Harkness, Moore, Murchison, Nicol and other authors. Many of these specimens were transferred from the collection presented by the Geological Society. Another addition is a series of casts of important

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specimens from the Box Stones of Suffolk, made and presented by Mr. Alfred Bell. Thin sections of *Bennettites maximus* Carr., from the Lower Greensand of the Isle of Wight, have been cut from the type-specimen diagnosed by W. Carruthers in 1870. These have been studied by Dr. Marie Stopes, who has published an account of the structure, with special reference to the cones.[1]

The following specimens in the Museum have been figured and described:—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1916. (PUBLISHED 1918).

The Fossil Fishes of the English Wealden and Purbeck Formations.

By DR. A. SMITH WOODWARD, F.R.S.

Mesodon sp., pl. xiii, f. 4, p. 58.
Coelodus arcuatus *A.S.W.*, pl. xiii, f. 5, p. 70.
Microdon radiatus *Ag.*, pl. xiv, figs. 5, 6, pp. 61, 62.
Coelodus multidens *A.S.W.*, pl. xv, f. 12, p. 68.
Ophiopsis breviceps *Eg.*, pl. xvi, f. 3, p. 74.
Aspidorhynchus fisheri *Eg.*, pl. xx, f. 3, p. 99.
Pholidophorus ornatus *Ag.*, pl. xx, f. 8, p. 105.

A Monograph of the British Palæozoic Asterozoa.

By Mr. W. K. SPENCER, M.A.

Lepidaster grayi *Forbes*, pl. vii, figs. 1–5, p. 117.
Salteraster asperrimus (*Salter*), pl. xi, figs. 3, 4, p. 150.
Salteraster ? imbricatus (*Salter*), pl. xi, f. 5, p. 152.
Salteraster ? coronella (*Salter*), pl. xi, f. 6, p. 153.
Protarthraster longimanus (*Whidb.*), pl. xiii, figs. 3–5, p. 164.

The Pliocene Mollusca of Great Britain.

By MR. F. W. HARMER, M.A.

Cypraea (Erosaria) spurca (*Linné*), pl. xxxiii, f. 8, p. 304.
Sipho latericeus (*Moeller*), pl. xxxvii, f. 14, p. 374.
Raphitoma concinnata (*S. V. Wood*), pl. xxxix, f. 3, p. 382.
„ compacta (*E. & B.*), pl. xxxix, f. 7, p. 385.
„ hoernesi (*Mayer*), pl. xxxix, f. 8, p. 387.
Admete viridula (*Fab.*) *v.* couthouyi (*Jay*), pl. xxxix, f. 48, p. 407.
Merica contorta (*Bast.*), pl. xl, f. 5, p. 394.
Sveltia lajonkairei (*Nyst*), pl. xl, f. 18, p. 397.
Cerithiopsis metaxae (*Delle Chiaje*), pl. xli, f. 19, p. 422.
„ tuberculoris (*Mont.*), pl. xli, f. 20, p. 420.
Triforis perversa (*Linné*), *v.* adversa (*Mont.*), pl. xli, f. 25, p. 425.

IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SER. B. VOL. 208.

New Bennettitean Cones from the British Cretaceous.

By MARIE C. STOPES, D.Sc. (Lond.), Ph.D

Bennettites maximus *Carr.*, pl. xxiii, figs. 1, 2, 7; pl. xxiv, figs. 1–6; text-figs. 23, 24, pp. 415–433.

IN THE GEOLOGICAL MAGAZINE, VOL. V. 1918.

By MR. ALFRED BELL.

Astarte kickxi *Nyst*, pl. iv, f. 16 (p. 417 in vol. for 1917).

By MR. T. H. WITHERS,

Pecten sp. (*Pollicipes alatus* of R. Tate), p. 171.

[1] *Phil. Trans. Roy. Soc.*, B, vol. 208, pp. 415–433, 1918.

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SCOTLAND.

As Dr. G. W. Lee was engaged on economic questions, no systematic palæontological work was done beyond the examination of cores from borings for coal and oil-shale. In several cases the results of this work were of direct economic value.

VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Museum remained closed during the year 1918, except for special inquiries.

LIST OF DONATIONS DURING THE YEAR 1918.

ADMIRALTY RESEARCH DEPARTMENT (THROUGH DR. R. BOYLE). Specimens of quartz showing twinning and parallel joint, etc.

BELL, A., ESQ.—A series of casts of Mollusca from the Suffolk Box-stones.

BOILLARD, MONS. M.—A polished and moulded slab of Lunelclair marble and two small slabs of Napolèon marble.

BOYLE, DR. R. (See ADMIRALTY RESEARCH DEPARTMENT).

BRITISH MUSEUM, TRUSTEES OF (THROUGH DR. G. T. PRIOR, F.R.S.)—A series of duplicate samples of Coal, Brown Coal and Peat from a Collection formed by the Austrian Government for the International Exhibition, London, 1862.

CLARK, E. STUART, ESQ.—Two pebbles of quartzite found in the Crown Coal, Llay Hall Collieries, Denbighshire.

DIATOMITE COMPANY, LTD., MESSRS. THE.—A series of samples of diatomite illustrating the products of the Company.

DICK, A.B., ESQ.—Slides and residues of Hampstead Sands. One specimen of slag from Deeside Lead Works, Bagillt, Flint. Two slides of Dr. Stead's (same material).

EDGE, LIEUT. A. BROUGHTON.—Micaceous hæmatite from Kelly Mine, Lustleigh, Devon.

FENTON, S. J., ESQ.—A miner's pick replaced by copper-ore, from Gulf Creek Mine, New South Wales.

FOULKES, LIEUT.-COL., I.M.S.—A series of interesting Alkaline rock specimens from Aden.

FRANCIS, REGINALD, ESQ.—Specimens of Calamine from the English Crown Spelter Company's Mines, Bergamo, Italy.

GREEN, J. F. N., ESQ., B.A.—*Didymograptus v. fractus* (Salter) cf. var. *volucer* Nich. from the Skiddaw Slates of Mungrisdale Quarry, Cumberland.

HALL, LIEUT. T. CLIFFORD, R.E., F.G.S.—A trilobite from the Stiper Stones of Shropshire.

HALLIMOND, A. F., ESQ., B.Sc.—Thirteen specimens of slag, etc., from the Malleable Steel Works, Stockton-on-Tees, also six specimens of slags.

HOLWELL IRON COMPANY, LTD., MESSRS. THE.—Four specimens of Ironstone from the Company's workings.

HONYMAN-GILLESPIE, MRS., TRUSTEES OF THE LATE.—Two polished blocks of Torbanehill Mineral.

HOWLETT, CHARLES E., ESQ., I.S.O. (H.M. OFFICE OF WOODS AND FORESTS).—A small collection of Gold ores from Wales, and a specimen block of Tintern Abbey Stone.

LAMONT, CAPT. A.E., R.A.M.C.—Moderately large specimen of coarse actinolite schist from bed of stream, Paprial Valley, Krusha, Balkan Range, Macedonia.

LAWN, DAVID, ESQ.—A model of the North Pit Ore-body, Park Mines, Dalton-in-Furness. (Made by Herbert Lawn, Esq.)

LOCKHART, W. S., ESQ., M.Inst C.E.—Block of Chinese Chalcedony drilled with the appliances previously presented to the Museum by Dr. Lockhart.

MATHER, R., ESQ.—Specimen illustrating a mode of formation of a volcano.

MICHIE, MRS. A series of mineral specimens from Broken Hill, New South Wales. A series of framed photographs of Broken Hill Mines, and a Show Case.

MUIR, J. M., ESQ.—Seven rock specimens from Oil-field in Mexico, San José de la Rusias. Three specimens of sand from Oil-well. One specimen of basalt from well.

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MURGATROYD, S. L., ESQ.—Calcareous infilling in pipe exhibiting tubular structures, from Brackley, Northants.

OSMAN, CHARLES W., ESQ.—Two specimens of schist, from Wisedom Farm Quarry, Devonshire. Two specimens of Chiastolite Slate from same quarry. Model of interpenetration twin of pyritohedron.

PRIOR, DR. G. T., F.R.S. (*See* BRITISH MUSEUM.)

REDWOOD, SIR BOVERTON, BART., D.Sc., F.R.S.E.—A specimen of peculiar weathering in the oil shale of Watson, Utah, U.S.A.

RONALDSON, R. K., ESQ.—A specimen of Talc from Southern Rhodesia.

RUSSELL, CAPT. A.—Four rock specimens from the lode at Strontian, N.B. Two from Tounnadashan Mine, Loch Tay. Four from Erines Mine, near Tarbert, Argyll. Twelve from Perthshire. Chromite of Coire Charmaig, Glen Lochay, N.B.

SCULLY, GERALD C., ESQ.—Tantalite, spodumene and lepidolite, from the pegmatites near Jackal's Water, N.N.E. of Steinkopf, Namaqualand. Also two crystals of Corundum from mica-schist from same district.

SHERBORN, C. DAVIES, ESQ., F.Z.S., ETC.—A selection of fossils from the Devonian of Cornwall, collected by the late Upfield Green, Esq., F.G.S.

SIMON, DR. A.—Specimens of Antimony Ore, from the Glendinning Mine, Dumfries.

TEALL, SIR J. J. H., F.R.S., ETC.—Two rock specimens (1) Hypersthene Andesite from the Cheviots (2) Dolerite from near Belfast.

TRECHMANN, C. T., ESQ., D.Sc.—Two specimens from Boring from Warren Cement Works, Hartlepool. One specimen from beneath Red beds on north side of Tees near Chemical Works.

WALFORD, E. A., ESQ., F.G.S.—A specimen of Ketton Stone from Stonesfield.

WEARDALE STEEL, COAL AND COKE COMPANY, LTD., MESSRS. The.—A sample of Silica-brick.

WEDD, C.B., ESQ., B.A.—Five fossils from the Cretaceous rocks of Lincolnshire.

WHITAKER, W., ESQ., F.R.S., ETC.—One specimen of Reading Beds containing yellow transparent resin or amber.

WILD, MESSRS. WILLIAM & SONS.—Samples of clay from Voel, the Gate Vein, and the Quarry Vein, Holyhead.

WOODS AND FORESTS, H.M. OFFICE OF (SEE HOWLETT, C.E., Esq.).

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MEMOIRS.

PUBLISHED MEMOIRS.

Special Reports on the Mineral Resources of Great Britain:—

Vol. III.—Gypsum and Anhydrite. By R. L. Sherlock, D.Sc., and B. Smith, M.A.; and Celestine and Strontianite. By R. L. Sherlock, D.Sc. Second Edition, 64 pp.; 4 text-figures. 1918. Price 2*s.* net.

Vol. V.—Potash-Felspar—Phosphate of Lime—Alum Shales—Plumbago or Graphite—Molybdenite—Chromite—Talc and Steatite (Soapstone, Soaprock and Potstone)—Diatomite. By A. Strahan, Sc.D., LL.D., F.R.S.; J. S. Flett, D.Sc., LL.D., F.R.S.; and C. H. Dinham, B.A.; with contributions by the late C. T. Clough, M.A., LL.D.; T. Eastwood, A.R.C.S.; and A. F. Hallimond, B.A. Second Edition. 43 pp.; 3 text-figures. 1917. Price 1s. net.

Volume VI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite Resources and Geology. 233 pp.; 3 plates; 8 text-figures, 1918. Price 7s. 6d. net.

Volume VII.—Lignites, Jets, Kimmeridge Oil-Shale, Mineral Oil, Cannel Coals, Natural Gas. Part I.—England and Wales. By A. Strahan, Sc.D., LL.D., F.R.S., with contributions by J. Pringle. 69 pp.; 1 plate; 3 text-figures. 1918. Price 2s. 6d net.

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Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1917. 55 pp. 1918. Price 2s. net.

The Water Supply of Essex from Underground Sources. By W. Whitaker, B.A., F.R.S., and J. C. Thresh, M.D., D.Sc., D.P.H., F.I.C. The Rainfall, by H. R. Mill, D.Sc., LL.D. 510 pp.; 4 plates. 1916. Price 15s.

SCOTLAND.

I.—MAPS.

(a) One-inch Maps, Colour Printed.

Sheet 74. Solid and Drift Geology. Price 2s. 6d. each.
Sheet 83. Solid and Drift Geology. Price 2s. 6d. each.

(b) Six-inch Reference Maps,

The following copies of six-inch maps have been completed and deposited in the office for reference. These are whole sheets, each consisting of four quarter sheets, except where otherwise stated.

Argyll, 33, 34 N.W., S.W., 47, 48 N.W., S.W.; 61 N.W., N.E. (Island of Oigh Sgeir), 64 N.E., S.E.

Ayr (new series) 55 N.E., S.W., S.E.; 56, 60 S.E.; 61, 62, 63 N.E., S.E.; 66, 69 N.E., S.W., S.E.

Inverness 2 N.E., S.W., S.E.; 3 S.W., S.E.; 4 N.E., S.W., S.E.; 5, 12, 59, 73, 74, 87, 88, 89, 103, 104, N.W., S.W.; 118, 119 N.W., S.W.; 153, 154 S.W., S.E.; 163, 164 N.W., N.E., S.W.; 169 N.W., N.E., Islands of Canna, Sanday, Rum, Eigg and Muck, 53 S.W., S.E., with 54 S.W.; 59 N.W., N.E., S.W.; 69 N.E., 70 N.W., S.E.; 72 N.E., S.W., S.E.; 73 N.W.; 74 N.W., N.E.

Lanark (new series) 25 S.W., S.E.; 32 N.E.

Nairn, 9.

Perth, 9 N.E., S.W., S.E.; 18, 25 N.E., S.E.; 26, 27, 34, 35, 36, 44 N.W., N.E., S.E., with 33a S.E., and 43a N.E.

Ross 77, 78, 100, 101 N.W.

Sheets formerly clean-copied but not reported as deposited, which have now been checked, revised and deposited.

Fife, 3, 4 N.E., S.W., SE.; 5, 6, 7 N.W., S.W.; 8 S.E.; 12, 13 N.W., S.W., S.E.; 14 N.E., S.W., S.E.; 15, 17, 18, 21, 22, 26, 27 N.W.; 38 N.W., N.E.; 39.

Renfrew, 1, 2, 3 N.W., S.W., S.E.; 4 S.W.; 5, 6, 18 N.W., N.E., S.E.; 19.

Stirling, 8 S.W., S.E.; 9 S.W., S.E.; 10, 14, 15, 16, 20, 21, 22, 26 N.W., N.E., S.E.

Dumbarton 15, 17, 18, 19, N.W., S.W., S.E.; 21 N.E.

Ayr, 1, 2, 3, 5, 6, 10 N.E., S.E.; 55, 60, 61, 65, 66, 69.

Wigtown, 4.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Summary of Progress for 1917. See above.

Special Reports on the Mineral Resources of Great Britain.

Volume V (2nd edition) see p. 35.

Volume VI see p. 35,

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APPENDIX I.

The Faunal Characters and Correlation of the Concealed Mesozoic Rocks in Kent.

By F. L. Kitchin, M.A., Ph.D.

The investigation of Mesozoic fossils obtained from numerous deep borings and a few shaft-sinkings in Kent has been referred to in the three previous issues of the 'Summary of Progress.' Large suites of specimens have been examined during the last few years[1] and the results will appear in a Memoir which will supplement the account of the four sections already published.[2] The present summary of the palæontological results is complementary to an account of the stratigraphy published two years ago.[3] From the sketch-map published there (p. 47) it can be seen that the majority of the newer sections investigated[4] lie to the north of the line Dover-Brabourne. The map also shows the relation of the localities in East Kent to the buried outcrops of the Jurassic formations.

The Triassic rocks, met with in the Brabourne boring only, have proved barren. No fossils have come into our hands from strata overlying the Gault. The specimens studied since 1911 came from formations ranging from the upper zones of the Lower Lias up to the Gault, inclusive. The sequence, however, is incomplete, for part of the Upper Lias and Inferior Oolite is absent by reason of an unconformity, and the upper parts of the Upper Kimmeridge Clay are known only at Pluckley and Penshurst; also, the Purbeck Series has not been proved east of Brabourne, and the Portland beds are present only at Ottinge and farther to the west.

Considering the necessarily imperfect evidence obtainable from the small quantity of rock in the cores, even when supplemented in a few cases by the material from three or four shafts, it is remarkable how clearly the main palæontological features of the separate divisions are recognisable. The great majority of the fossils were the remains of lamellibranchs. Whenever available, ammonites have been utilised as guides to correlation, but in many cases it has been necessary to rely on the imperfectly known bivalves, either singly or collectively, and not without success. Within so limited an area, lateral changes of lithological facies are not so great as to bring about any radical change of faunal

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[1] Mr. G. W. Lamplugh and Mr. J. Pringle examined the materials at the sites: Mr. Pringle has shared with the writer the task of studying the fossils in detail.

[2] 'The Mesozoic Rocks in some of the Coal Explorations in Kent,' *Mem. Geol. Survey*, 1911.

[3] 'The Underground Range of the Jurassic and Lower Cretaceous Rocks in East Kent.' Appendix IV., in 'Summary of Progress' for 1916, *Mem. Geol. Survey*, 1917, p. 45.

[4] We are much indebted to Dr. M. Burr and Mr. E. O. Forster Brown for permission to visit the borings respectively under their charge and, where possible, to make representative collections. In the case of the older Ottinge boring (1898-9) we were not favoured by similar facilities; but by the kindness of Dr. G. Hickling, specimens of the Kimmeridge and Portland rocks from that boring, now preserved in the Manchester Museum, have been placed in our hands for examination.

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characters; indeed, there is a degree of uniformity which has greatly aided correlation. At many horizons the faunas show close agreement with those made familiar at the outcrops in this country. As regards the Jurassic rocks, in some formations there can be recognised close faunal community with Continental deposits, be it the nearer developments in France and Switzerland or the more distant representatives in Russia.

The conditions are different when we study the fossils with reference to vertical succession and zonal delimitation. Successive beds or groups of beds showing marked lithological changes frequently exhibit faunal contrasts more abrupt than would result merely during the passage of time. Faunal characterisation may thereby become accentuated, introducing a certain relief as between contiguous strata; and this sometimes compensates for the scantiness of the usual criteria for zonal subdivision.

The evidence of fossils has enabled us to gauge the magnitude of the unconformities shown in the sections. Thus it has been possible to prove the varying position in the Upper Lias at which the Lias-Oolite unconformity occurs, and to demonstrate that the basal sands of the Oolite Series are of Inferior Oolite age at Dover, but of Great Oolite age at Snowdown and Bere Farm. Similarly, we have been enabled to determine precisely the position at which the upward sequence in the Jurassic series is interrupted by the unconformable junction with the Wealden Beds, a descending line when traced in a north-easterly direction. The fossils, again, have revealed a well-marked break above the Kimmeridge Clay at Ottinge and Brabourne, involving the absence there of the higher parts of the formation and probably of some basal portion of the Portland Beds also. The palæontological evidence, in providing a key to the true reading of the Kimmeridge Clay, has rendered it possible to show further that the easterly thinning of the formation is due only in part to a true attenuation, and is largely attributable to erosion of the upper portions, as shown at Abbotscliff and Dover. The influence of the two factors can be estimated with approximate accuracy, a result that was unattainable on lithological evidence. In the Cretaceous rocks the fossil-evidence suggests that some lower part of the Atherfield Beds is absent and that, north-east of Folkestone, there is also a non-sequence between the Atherfield Clay and the Sandgate Beds above. Similarly there is evidence, chiefly of a negative character, to suggest the existence of a break between the Folkestone Beds and the Gault.

In the present sketch it is possible only to indicate briefly the chief characteristics of successive beds and the principal evidence on which our correlations have been based. The presentation of fuller detail is reserved for the forthcoming Memoir.

Lias.—This formation is found everywhere to be imperfect, though there is almost always some representation of the Lower, Middle and Upper subdivisions. There is a remarkable condensation in an easterly and north-easterly direction, as shown at Dover, Bishopsbourne and Fredville. The lowest beds at Brabourne may be ascribed to the Jamesoni Zone. They are poorly characterised

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by fossils, but this correlation is strongly suggested by the presence of *Rhynchonella rimosa* (v. Buch) and *Lima antiquata* J. Sow., and of *?Polymorphites trivialis* (Simps.) a little higher up. The ferruginous basement-bed at Folkestone, yielding *Lima antiquata*, may belong to the same zone, while the presence of *Rhynchonella rimosa* and *Lima antiquata?* in the base of the much-condensed Lower Lias at Dover suggests a similar correlation there. At most localities the base is not below the Capricornus Beds, which are palæontologically well characterised in Kent. These clays have yielded *Androgynoceras maculatum* (Y. and B.), *A.* cf. *lataecosta* (J. de C. Sow.) and *Oistoceras arcigerens* (Phill.). The numerous bivalves include small well-ribbed species of *Astarte*, *Grammatodon intermedius* (Simps.), a characteristic *Nuculana* and *Unicardium cardioides* Phill. A *Spiriferina* resembling *S. rostrata* (Schloth.) occurs locally. At Chilton there is great condensation, with a basal limestone-band containing rolled specimens of *Montlivaltia*.

The Middle Lias comprises a thin shaly member in its lowest part, which may be allocated to the Margaritatus Zone, and a thicker limestone-series above, ascribable in the main to the Spinatus Zone. No ammonites have been seen and the zonal junction cannot yet be fixed. The Margaritatus-shale contains a bivalve-fauna which includes *Modiola scalprum* J. Sow., *Myoconcha decorata* (Münst.), *Protocardia truncata* (J. de C. Sow.) and an undescribed *Nuculana* characteristic of the same zone in the Midlands. A shallowing of the sea at the close of Capricornus-time is shown at Chilton by a pebbly bed at the base of the Middle Lias, while the absence of the Margaritatus-shale marked a break in deposition at Harmansole. The limestone-series above is always characterised by *Pecten aequivalvis* J. Sow., *P. liasianus* Nyst and abundant Rhynchonellids. These include *Rhynchonella capitulata* Tate, found only in the Spinatus Zone elsewhere; but the more common species are *R. fodinalis* Tate, *R. northamptonensis* Dav., *R. tetrahedra* (J. Sow.) and comparable forms. *Belemnites breviformis* Voltz was also met with. An unusual feature is the rarity of Terebratulids.

At Harmansole the Lias-Oolite unconformity cuts down to the Middle Lias. At Chilton and Fredville it occurs a little higher, so that there is a thin capping of sandy limestone representing the Annulatus Zone (Acutum + Tenuicostatum), which is very scantily developed throughout the area. Lithologically continuous with the underlying beds, it is marked off by the sudden appearance of *Dactylioceras tenuicostatum* (Y. and B.) and similar finely-ribbed forms. The overlying lowest member of the Serpentinus Zone is developed as a clay or clay-shale, as seen at Bishopsbourne, Dover, Elham, Folkestone and Ropersole; it may be correlated with the Exaratum Zone of Mr. Buckman. The ammonites include *Dactylioceras delicatum* (Simps.), while the chief associated fossils are *Orbiculoidea reflexa* (J. de C. Sow.), an undescribed oyster and a *Corbula*, abundant and characteristic of the bed. A higher level in the Serpentinus Zone (Falcifer-Pseudovatum beds of Mr. Buckman) is represented at Bishopsbourne, Elham and Folkestone. Here were found *Harpoceras mulgravium* (Y. and B.), *H.* cf. *strangewaysi* (J. Sow.), *Hildoceras*

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levisoni (Simps.), *Dactylioceras spp.* and *Belemnites subtenuis* (Simps.). At Brabourne and Elham a still higher bed represents the Communis Zone (Subcarinatum-Fibulatum of Mr. Buckman), with a species of *Dactylioceras* comparable with *D. commune* (J. Sow.), *Hildoceras walcotti* (J. Sow.), *Peronoceras attenuatum* (Simps.) and *Porpoceras andraei* (Simps.). Mr. Buckman has considered that a still higher zonal level is reached below the unconformity at Brabourne, as indicated by a *Grammoceras* resembling *G. striatulum* (J. de C. Sow.).

Inferior Oolite.—It was suggested in the Memoir of 1911 that some basal part of the Oolites at Dover and Brabourne might be correlated with the Inferior Oolite. Fossils obtained at Dover have since provided the desired proof. In the lowest sandy beds an abundant bivalve-fauna has been found, pointing to a position within the Parkinsoni Zone. Among 25 species collected from shaft-material, there occurred abundantly such typical shells as *Gresslya abducta* (Phill.) and *Pholadomya fidicula* J. Sow., as well as *Opis* (*Pachyopsis*) *cordiformis* Lyc. There were also some *Trigoniae* of the *duplicata*-group, suggesting a position in the Garantiana Zone or perhaps a little higher. No ammonites were seen. Many of the lamellibranch-shells show pronounced abrasion. The lowest few feet of Oolites with sandy base at Elham also probably belong to the Inferior Oolite.

Great Oolite and Forest Marble.—The lowest part of this series is represented at Brabourne and Elham by shales and limestones of Fullonian type, but eastwards, at Fredville and Bere Farm, in closer proximity to the shore-line of the period, the basal beds become more sandy. At Elham the lowest beds yielded *Trigonia signata* Ag., indicating a Lower Fuller's Earth horizon (of *zig-zag—fusca* age); there occur also abundant specimens of *Pteria* (*Oxytoma*) *inequivalvis* (J. Sow.) and a coarsely-ribbed *Astarte*, as in the corresponding deposits at Brabourne. The sandy beds at Fredville and Bere Farm also appear to occupy a position below the Fuller's Earth Rock. They contain an abundant fauna, chiefly bivalves, including some common forms of the Great Oolite. *Thamnastraea lyelli* Edw. and Haime and *Rhynchonella lotharingica* Haas were also found, the latter pointing to a position within the *zig-zag—acuminata* beds; a *Pleuromya*, abundant also in the Lower Fuller's Earth of Wiltshire, supports the correlation. *Homomya gibbosa* (J. Sow.) and *Pholadomya murchisoni* Moesch, well suited to the sandy conditions, are common at Fredville (Snowdown shaft).

A slightly higher zonal level is represented by the limestones and sandy beds at Tilmanstone, Maydensole and Oxney, as indicated by *Ostrea acuminata* J. Sow. and *Trigonia clavulosa* Rig. and Sauvage. Thus, as we pass in a north-easterly direction from a line drawn between Elham and Dover Colliery, not only is the Inferior Oolite absent, as at Bere Farm, Chilton and Fredville, but the base of the Oolites occurs at a rising level in the series. At Betteshanger, north-east of Tilmanstone, the lowest Oolite beds approximate in type to those in the higher part of the Great Oolite throughout the district. Above the *acuminata*-horizon zonal indications are scanty; but there is a transition through beds with *Rhynchonella* cf. *hopkinsi* Dav. up to purer

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oolite-limestones with *Terebratula bathonica* (S. Buckm.). Fossils are sparingly present, on the whole.

The more impure and variable beds of the Forest Marble contain a bivalve-fauna continuing the general characters of that in the limestones below. But here we find *Gervillia crassicosta* Morr. and Lyc. at its maximum, both in respect to numbers and the size of the valves, while distinctive faunal elements are provided by *Terebratula marmorea* Opp., *Astarte fimbriata* Lyc. and *Perna obliqua* Lyc., with undescribed species of *Modiola* and *Astarte* unknown at other zonal levels.

Cornbrash.—This formation is developed as a series of limestones, some of which are rubbly, with a band of clay at the top. It is palæontologically well marked off from the Forest Marble. *Macrocephalites* was found in the limestones up to the base of the clay. The lower beds are highly fossiliferous, with a characteristic assemblage of species such as *Echinobrissus clunicularis* Wright, *E. orbicularis* (Phill.), *E. quadratus* Wright (common in this area), *Holectypus depressus* (Leske), *Microthyris lagenalis* (Schloth.), *Ornithella obovata* (J. Sow.), *Rhynchonella major* Desl. [*non* Sow.] and *Terebratula intermedia* J. Sow. The many associated lamellibranchs included *Pseudomonotis echinatus* (J. Sow.), typical in its abundance and robustness of type. The argillaceous bed at the top showed an absence of echinoids and rarity of brachiopods. Its bivalve-fauna is chiefly characterised by *Pholadomya phillipsi* Lyc. and an abundant *Pseudomonotis*, differing from the typical *Ps. echinatus* by weaker inflation and less strong and spinous ribbing.

Kellaways Rock.—A somewhat abrupt transition to the sandy and ferruginous Kellaways beds is accompanied by a marked faunal change. Only at Oxney, where *Proplanulites* was found at the base, was there definite representation of the Koenigi Beds, and the fact that no specimen of *Kepplerites* has anywhere been seen also points to the local absence or imperfect development of that zone. At most localities the formation is characterised throughout by a bivalve-fauna of relatively few species, though with a profusion of individuals. The commoner are gryphæate oysters of several stocks and an undescribed *Pseudomonotis*, larger than *Ps. echinatus*. The oysters are mostly of small size in the lowest beds, with an increasing proportion of larger individuals at successively higher levels. The large and abundant *Gryphaea bilobata* J. de C. Sow. is dominant in the upper beds. Ammonites are rare and include *Sigaloceras calloviense* (J. Sow.) and some forms of '*Cosmoceras*' similar to specimens which occur in the Calloviensis Zone of Wiltshire. The top bed has yielded numerous examples of *Belemnites oweni* Pratt.

Oxford Clay.—The marly clays of the 'Ornatus Beds' are characterised by brown-coated casts of *Cosmoceras* throughout. Finely ribbed forms commonly referred to *C. jason* (Rein.) occur at the base. *Erymnoceras* was found a few feet higher, suggesting a *coronatum*-horizon, while *Cosmoceras duncani* (J. Sow.) and *C. castor* (Rein.) occurred just above this. There is no sign of the *Reineckeia*-fauna (Anceps Zone) below or the Athleta Zone above. The clay contains innumerable casts of lamellibranchs, including undescribed species of *Astarte*, *Cucullaea* and *Nucula*.

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In the purer clays of the 'Renggeri Beds' fossils occurred more sporadically. *Quenstedtoceras* replaces *Cosmoceras* and is represented by *Q. macrum* (Quenst.), *Q. leachi* (J. Sow.), *Q. lamberti* (J. Sow.) and others. *Creniceras crenatum* (Brug.), *C. cristatum* (J. de C. Sow.) and species of *Hecticoceras* are characteristic. Some of the bivalves, such as *Grammatodon concinnus* (Phill.), *G. montaneyensis* (de Lor.) and *Nuculana roederi* (de Lor.), help to show the faunal connection with corresponding beds in the Bernese Jura.

In the highest part of the Oxford Clay ('Mariae Beds') the *Quenstedtoceras*-fauna is continued, but *Creniceras* and *Hecticoceras* are absent. There are specimens of *Perisphinctes* resembling *P. matheyi* de Lor. and *P. moeschi* de Lor. (Bernese Jura). The bivalve-fauna appears similar to that of the middle sub-division, but is more imperfectly known.

Corallian Series.—The lowest 25 ft.—35 ft. of this series are ferruginous and yield a *Cardioceras*-fauna including *C. nikitinianum* Lahus., *C. rouillieri* Lahus., *C. tenuicostatum* (Nik.) and others of Russian facies belonging to Pre-*cordatus* time. There are many associated bivalves, and towards the top of these ferruginous marlstones the presence of *Millericrinus*-stems recalls the corresponding 'Marnes à *Millericrinus*' near Boulogne. The succeeding grey limy marls show in their lower part a thin echinoid-bed with *Echinobrissus* and *Holectypus*, a large *Gryphaea* and *Perisphinctes variocostatus*? (Buckl.). This can be widely traced and is followed above by a conspicuous grey marlstone-band full of black-coated casts of shells, including *Perna cordati* Uhl., *Aspidoceras*, *Peltoceras arduennense* (d'Orb.) and *P.* cf. *eugenii* (d'Orb.). Correlation may be made with Hébert's Bed 15 in the section at Villers-sur-Mer. The fauna of the true Cordatus Zone (or Vertebrale Zone) has not been detected in Kent.

The limestones constituting the middle part of the formation contain *Cidaris florigemma* Phill. throughout. In their lower part they yield typical corals, with *Hemicidaris intermedia* (Flem.), *Glypticus hieroglyphicus* (Goldf.), *Ornithella delmontana* (Oppel) and *Pseudomelania heddingtonensis* (J. Sow.), among other fossils, recalling the 'Glypticien' in the Haute-Marne district. These beds merge up into purer cream-coloured limestones of 'Coral Rag' type, with abundant corals and a varied gasteropod-fauna in which *Nerinea tuberculosa* Defr. is most conspicuous.

The variable upper beds yield *Amoeboceras* in their lower part, while the 'millet-seed' ironstone falls in the Ringsteadia Zone, thus corresponding with the Westbury ironstone. Below it was found *Belemnites nitidus* Dollf.[*non* Phill.], a species of the Decipiens and Ringsteadia Zones elsewhere. The uppermost bed yielded only a bivalve-fauna with few zonal characteristics; but we believe the upper limit to fall at about the base of Salfeld's Zone of *Pictonia baylei*.

Kimmeridge Clay.—The Lower Clays, with *Exogyra virgula* (Defr.) and its smaller forerunners, comprise the Pictonia Beds up to the Gravesia Beds, inclusive. They yield *Ostrea deltoidea* J. Sow., *Gervillia kimmeridgensis* d'Orb., *Nucula menkei* F. A. Roem. and *Pecten kimmeridgensis* Cott. in their lowest part.

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At 10 ft.—30 ft. above the base the *Rasenia*-fauna is found, with *Physodoceras orthocera* (d'Orb.) and '*Holcostephani*' of earlier authors, such as '*H.*' *witteanus* (Opp.) and close congeners of '*H.*' *stephanoides* (Opp.) and '*H.*' *trimerus* (Opp.). The Rasenia Beds are developed in Dorset, in Lincolnshire (Market Rasen) and in Northern France (the Orthocera Beds); they correspond with the Tenuilobatus Zone (*s. str.*) of Crussol in Ardèche and Baden in Switzerland. The first appearance of *Protocardia morinica* (de Lor.) occurs some distance higher up, marking a position in the Aulacostephanus Zones of Salfeld's scheme. *Exogyra virgula* (Defr.) becomes increasingly large and abundant when traced upwards. It ranges probably to the top of the Gravesia Beds of Salfeld, marked by the Yellow Ledge at Kimmeridge. At Lower Standen the top of the Lower Clays has yielded *Gravesia* and a *Perisphinctes* resembling *P. bleicheri* (de Lor.), supporting the correlation. *Orbiculoidea latissima* (J. Sow.) is rare in the lower part of the Gravesia Beds but common near the top, though of smaller size than in higher zones. At Dover the eroded top of the Kimmeridge Clay falls just above the Rasenia Beds, but at Abbotscliff it is well up in the Aulacostephanus Beds. The Lower Clays are complete at Lower Standen and to the west, and thicken rapidly in that direction.

The Upper Clays, containing *Modiola autissiodorensis* but not *Exogyra virgula*, comprise the Virgatites Zone and higher beds up to the base of the Portland Stone Series, the deeper water argillaceous facies persisting in this area when Portland Sands are developed elsewhere. The Virgatites Beds are perhaps represented by their basal part at Elham. The whole of the zone is present at Ottinge and Brabourne, and perhaps also the base of the Pallasianus Zone; but an unconformity there cuts off the higher beds, as in Lincolnshire and Yorkshire. The Upper Clays are in full development at Pluckley and Penshurst, where they have thickened greatly.

The Virgatites Zone is characterised by small coarsely-ribbed forms of *Astarte*, *Lucina minuscula* Blake, *Modiola autissiodorensis* (Cott.), *Protocardia morinica* (de Lor.), an abundant undescribed *Aporrhais*, an undescribed *Cyprina* and other bivalves. *Pecten morini* de Lor. comes in at about the top and is commoner above. Some of the fragments of ammonites seen in the boring-cores appear to belong to *Pseudovirgatites* and *Virgatosphinctes*, and may include the true *Virgatites*, as in Dorset. There is also a small, delicately ribbed involute Perisphinctoid, common in the zone elsewhere. An important datum-line is furnished by the minute pyritized radial plates of the pelagic crinoid *Saccocoma*, seen at Penshurst (at 1,794 ft.—1,806 ft. depth), and since found by Mr. Pringle to characterise the Oil-Shale horizon at Corton and the Blackstone band and about 15 ft. of shales below it at Kimmeridge. The abundance and well defined vertical distribution of the plates in the two districts justifies us in establishing a Sub-zone of *Saccocoma*.

The Pallasianus Zone was best seen in its thick development at Penshurst (at about 1,300 ft.—1,500 ft. in depth). Numerous ammonites, fragmentary as preserved in the cores, indicate a well developed cephalopod-fauna of Russian facies, permitting com-

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parison with '*Holcostephanus*' *pallasianus* (d'Orb.), '*H.*' *panderi* (d'Orb.) and Michalski's figures of '*H.*' *lomonossovi*, '*Perisphinctes*' *stschukinensis* and other species. Two characteristic bivalves are a new *Grammatodon* and *Cyprina implicata* de Lor. The beds representing the higher zones yielded few fossils, and the data are insufficient for the purpose of subdivision. A fragment of a large '*Perisphinctes*' may possibly belong to '*P.*' *giganteus* (d'Orb.); among the bivalves there occurred *Ostrea bononiae* Sauvage.

Portland and Purbeck Beds.—The Portland Series, equivalent to the Upper Portland Beds of Dorset, is thickest at Penshurst and diminishes eastwards as shown at Brabourne and Ottinge. This is due partly to attenuation, but also, we believe, to the absence of some of the lower beds at those localities (where there is an unconformable base), a view supported by lithological evidence. Remains of *Perna* were numerous near the base at Penshurst but absent at the easterly localities. Ammonites found in the lower parts of the series at Brabourne and Penshurst are large specimens of '*Perisphinctes*,' incomplete in the cores. Comparison is permissible with '*P.*' *bononiensis* (de Lor.), '*P.*' *giganteus* (d'Orb.) and '*P.*' *giganteus* (J. Sow.). The bivalves, more numerous in the higher part of the series, include *Pecten* (*Camptonectes*) *lamellosus* J. Sow., *Modiola boloniensis* de Lor., *Pleuromya tellina* Ag. and *Trigonia gibbosa* J. Sow. The available data are insufficient for zonal subdivision.

No new information is forthcoming concerning the Purbeck Beds. The fresh-water strata, as previously described, contain the usual fauna of ostracods, *Cyrena*, *Unio* and *Viviparus*, while marine incursions about the middle part of the series are indicated, as in Dorset, by *Corbula alata* J. de C. Sow., *Ostrea distorta* J. de C. Sow., *Protocardia purbeckensis* (de Lor.) and other species.

Wealden and Lower Greensand.—The newer explorations have thrown no fresh light on the palæontology of the Wealden Beds.

The Atherfield Clay was penetrated in most of the borings, but cores were seldom available. Nearly all the fossils obtained had already been noted at Dover. The basal Perna Bed appears to be unrepresented. Ammonites of the *deshayesi*-group are distributed throughout the clay, and the association of species found in this deposit points to a correlation with the Lower Aptian (Bedoulien) of Kilian's classification.

Hythe Beds are probably present at Folkestone though absent farther east, where greensand of Sandgate type rests on the floor of Atherfield Clay and fills the numerous burrows of boring molluscs which penetrate it. Fossils found in the Sandgate Beds of the newer borings include *Rhynchonella latissima* (J. de. C. Sow.), *Trigonia caudata* Ag. and the rare *Anthonya cantiana* Woods.

No constant line can be drawn between the Sandgate and Folkestone Beds on palæontological evidence. Beds of Folkestone character vary in thickness according to local conditions, and beyond *Exogyra sinuata* (J. Sow.), they have yielded few fossils. A comparison with Continental deposits shows that the

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faunal representation is imperfect and suggests that the sequence is incomplete at the top.

Mammillatus Bed and Gault.—The lamellibranchs of the Mammillatus Bed comprise well-known species of the Gault, while the presence of ammonites of the groups of *Hoplites raulinianus* (d'Orb.) and *H. interruptus* (Brug.) strengthens the alliance with the clay above. Although the Mammillatus Bed is a condensed deposit, it probably represents only some upper portion of the strata on the Continent characterised by *Douvilleiceras mammillatum* (Schloth.) In Brunswick and South-Eastern France the lower part of the beds containing that species constitutes the Zone of *Leymeriella tardefurcata* (Leym.), marked by a distinctive ammonite-fauna of which no trace has been seen in Kent; this lower zone is also unrepresented in the Boulonnais. These facts further suggest the existence of a non-sequence between the Folkestone Beds and the Mammillatus Bed in Kent.

The few available boring-cores from the Gault Clay have yielded some of the typical fossils known at the outcrop, calling for no comment.

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APPENDIX II.

List of the Fossil Plants from the Coal Measures of the Borings at Bere Farm, Elham, Folkestone, and Lydden Valley, Kent.[1]

By Dr. R. Kidston, F.R.S.

Elham Boring, Elham, Kent.

Coal Measures entered at 1,598 ft.

Depth in feet.	
1,720, 2,162	Sphenopteris sp.
2,254	Alethopteris lonchitica *Schloth. sp.*
1,720	Lonchopteris rugosa *Brongn.*
1,975	Mariopteris muricata *Schloth. sp.*
1,845, 2,030	Neuropteris gigantea *Sternb.*
2.030	„ heterophylla *Brongn.*
2,032	„ microphylla *Brongn.*
2,118, 2,122...	„ tenuifolia *Schloth. sp.*
1,975, 2,030, 2,176... ...	„ spp.
1,944, 1,946	Calamites suckowi *Brongn.* [Rhizome]
2,074	*Cf.* Calamites suckowi *Brongn.*
1,820	Calamites undulatus *Sternb. sp.*
2,190	Calamitic cone
1,720	Asterophyllites equisetiformis *Schloth. sp.*
2,160	Sphenophyllum sp.
1,706	Lepidodendron sp.
1,706, 1,709	Lepidostrobus anthemis *König sp.*
1,726	Sigillaria laevigata *Brongn.*
1,744, 2,044, 2,196... ...	Stigmaria ficoides *Sternb. sp.*
1,720	Cordaites principalis *Germar sp.*
1,720	Carpolithus membranaceus *Göpp.*

The number of species identified from this boring is small, but the rocks from which they have been derived appear to belong to the Westphalian Series.

Bere Farm Boring, 1¾ miles N.E. of Dover.

Coal Measures entered at 1,358 ft.

Depth in feet.	
1,994	Sphenopteris *cf.* neuropteroides *Boulay sp.*
1,880–1,886...	Pecopteris *cf.* unita *Brongn.*
1,880–1,886, 2,684–2,690 ...	„ miltoni *Artis sp.*
1,994	„ *cf.* miltoni *Artis sp.*
2,684–2,690	„ *cf.* pennæformis *Brongn.*
2,684–2,690	„ *cf.* richardsoni *D. White* [Geol. of McAlester-Lehigh Coal Field Indian Territory. Report on the Fossil Plants. U.S. Geol. Survey 19th Ann. Rept., part iii, 1899, p. 492, pl. lxviii, figs. 2, 4, 3a, 4a.]
1,880–1,886, 2,550, 2,684–90	Pecopteris (Cyatheites) spp.
2,684–2,690...	Mariopteris muricata *Schloth. sp.*
2,684–2,690...	„ sp.
1,880–1,886, 2,055–2,056 ...	Alethopteris davreuxi *Brongn. sp.*
1,880–1,886...	Neuropteris macrophylla *Brongn.*
1,970	„ *cf.* macrophylla *Brongn.*
1,880–1,886, 1,970, 1,994, 2,005–2,008, 2,911, 2,924, 2,984–2,990, 2,630–2,635	„ scheuchzeri *Hoffm.*

[1] For a brief account of the first three of these sections see 'Summary of Progress' for 1916, *Mem. Geol. Surv.* 1917, p. 34.

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Depth in feet.	
2,634–90	Neuropteris missouriensis *Lesqx.*
1,880–1,886, 2,550, 2,684–2,690	„ ovata *Hoffm.*
2,630–2,635...	„ obliqua *Brongn. sp.*
1,975, 1,995, 2,348, 2,630–2,635, 2,911	„ rarinervis *Bunbury*
1,880–1,886, 2,684–2,690, 2,924, 2,944	„ *cf.* rarinervis *Bunbury*
2,550, 2,911	„ microphylla *Brongn.*
2,630–35, 2,684–2,690, 2,944	„ spp.
2,944	Odontopteris lindleyana *Sternb.*
1,880–1,886, 2,005–2,008 ...	„ *cf* lindleyana *Sternb.*
2,944	Linopteris munsteri *Eichw. sp.*
1,944	Aphlebia sp.
1,926, 1,950, ...	Calamites suckowi *Brongn.*
1,990	„ *cf.* suckowi *Brongn.*
1,920, 2,684–2,690... ...	„ sp.
1,880–1,886, 2,684–2,690, 2,944	Annularia sphenophylloides *Zenker sp.*
1,880–1,886	„ stellata *Schloth. sp.*
1,880–1,886, 2,081... ...	Cordaianthus spp.
2,005–2,008...	Palaeostachya elongata *Presl. sp.*
1,880–1,886, 2,005–2,008 ...	Sphenophyllum emarginatum *Brongn.*
2,684–2,690...	Sigillaria tessellata *Brongn.*
1,864, 2,754	Stigmaria ficoides *Sternb. sp.*
2,911	Cordaites palmæformis *Göpp. sp.*
1,880–1,886, 2,085... ...	„ sp.
1,920	Samaropsis arberi *Kidston* n. sp. [*Cornucarpus acutus* Arber (*non* L. and H. sp.) *Annals of Bot.*, vol. xxviii, p. 97, pl. vi, fig. 14 and text fig. 2, 1914.]
1,880–1,886...	*Cf.* Trigonocarpus sp.

The rocks passed through in the uper part of this bore, from 1,864 ft. to 2,085, are referable to the Keele Group of the Radstockian Series, and from 2,348 ft. to 2,944 ft. to the Etruria Marl Group of the Staffordian Series.

Owing to our imperfect knowledge of the fossil plants of the Staffordian Series, the zoning of these rocks offers considerable difficulty, but the flora observed between the depths of 2,348 ft. and 2,944 ft. seems to indicate a higher horizon than the Black-band Group of the Staffordian Series.

If the Newcastle Group is present, it must lie between the depths of 2,085 ft. and 2,348 ft., from which no fossil plants have been collected.

Boring at Tower Brickworks, Folkestone, Kent.

Coal Measures entered at 1,487 ft.

Depth in feet.	
1,780, 2,072	Sphenopteris obtusiloba, *Brongn., forma* convexiloba *Schimper*
1,768, 1,980...	„ chærophylloides *Brongn. sp.*
1,636	„ *cf.* artemisiæfolioides *Crépin*
1,768	„ herbacea *Boulay*
1,585, 1,792–1,795... ...	„ sp.
1,590, 1,996, 2,914... ...	Eremopteris artemisiæfolia *Sternb. sp.*
1,636	*Cf.* „ „ „
1,980, 2,950–2,955, 3,095–3,097	Pecopteris miltoni *Artis sp.*
1,760	„ oreopteridia *Schloth. sp.*
2,950–2,955...	„ bucklandi *Brongn.*

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Depth in feet.	
1,548–1,552, 1,590, 1,678, 1,764, 1,980, 2,044, 2,990–2,993, 3,290	Pecopteris (Cyatheites) sp.
1,620, 3,095–3,097... ...	Dactylotheca plumosa *Artis sp.*
1,784–1,787	Mariopteris muricata *Schloth. sp.*
1,647–1,649, 1,784–1,787 ...	„ „ „ *forma* nervosa *L. and H., pro sp.*
1,647–1,649	„ sp.
1,690–1,715	Alethopteris serli *Brongn. sp.*
1,715, 2,072	„ aquilina *Schloth. sp.*
1,760	Odontopteris *cf.* lindleyana *Sternb.*
1,548–1,552, 1,647–1,649, 1,780, 1,784–1,787, 1,792–1,795, 1,846, 1,980, 2,019, 2,044, 2,635–2,640, 2,990–2,993, 3,290, 3,298	Neuropteris scheuchzeri *Hoffm.*
1,647–1,649, 1,837–1,840, 1,846	„ flexuosa *Sternb.*
1,647–1,649...	„ „ „ *forma* rotundifolia *Brongn. pro sp.*
1,792–1,795, 1846	„ fimbriata *Lesqx.*
1,548–1,552, 1,690, 1,708–1,710, 1,780, 1,784–1,787, 1,792–1,795, 1,780, 1,873, 2,242, 2,765, 2,790	„ rarinervis *Bunbury*
2,780	Neuropteris *cf.* callosa *Lesqx.*
1,792–1,795...	„ ovata *Hoffm.*
2,760	„ *cf.* grangeri *Brongn.*
1,846	„ gigantea *Sternb.*
1,837–1,840...	„ sp. [*N. squarrosæformis* Kidston MS.]
1,647–1649, 1,837–1,846, 1,980, 2,806, 2,950–2,955, 2,990–2,993, 3,286, 3,295	„ spp.
1,548–1,552, 1,585, 1,620, 1,647–1649	Calamites suckowi *Brongn.*
1,536, 1,548–1,552, 1,620, 1,784–1,787, 1,816, 2,483–2,484, 2,890	„ spp.
1,548–1,552, 1,747	Calamitic cone.
1,747	Annularia galioides *L. and H. sp.*
1,647–1,649, 1,708–1,710, 1,715, 1,873, 1,969, 1,980, 2,826, 2,950–2,955, 3,095–3,097	„ sphenophylloides *Zenker sp.*
1,708–1,710, 1,980, 2,284, 2,635–2,640	„ stellata *Schloth. sp.*
1,780	„ *cf.* „ „
1,660	Asterophyllites longifolius *Sternb. sp.*
1,792–1,795...	Stachannularia tuberculata *Sternb. sp.* [axis of cone]
1,647–1649, 1,980, 2,044 ...	Sphenophyllum emarginatum *Brongn.*
1,780	„ majus *Bronn sp.*
1,590, 1,980	„ sp.
1,846	Lepidodendron fusiforme *Corda*
1,846	„ rimosum *Sternb.*
1,784–1,787, 2,019	„ sp.
1,780, 3,095–3,097	Lepidophyllum anthemis *König sp.*
1,980	„ lanceolatum *L. and H.*
1,792–1,795	Lepidophyllum majus *Brongn.*
1,780, 2,635–2,640... ...	„ sp.
1,980	Lepidostrobus sp.
2,019	Sigillaria sp.
2,019, 3,095–3,097... ...	Sigillariophyllum sp.
1,578.	Stigmaria ficoides *Sternb. sp.*

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Depth in feet.	
1,708–1,710, 1,950... ...	Cordaites borassifolius *Sternb. sp.*
1,748, 1,750, 1,980... ...	„ *cf.* palmaeformis *Gopp. sp.*
1,490, 1,768	„ sp.
2,591	Dadoxylon sp.
1,715	Carpolithus membranaceus *Göpp.*
1,647–1,649...	Holcospermum mamillatum *Lesqx., sp.* [*Rhabdocarpus mamillatus*, Lesqx., Coal Flora, vol. iii, p. 816, pl. cx, figs. 39–42, 1884]
2,242	Samaropsis arberi *Kidst.* [*Cornucarpus acutus* Arber (*non.* L. and H. sp.). *Annals of Bot.*, vol. xxviii, p. 97, pl. vi, fig. 14 and text fig. 2, 1914.]
1,980	Samaropsis crassa *Lesqx.*
1,715	„ reniformis *Geinitz sp.* [*Cardiocarpon reniforme* Geinitz. Leitpflanzen des Rothl. u. d. Zechsteingebirges oder d. perm. Formation in Sachsen, p. 18, pl. ii, figs. 15, 16, 1858]
1,764	Samaropsis fluitans *Auctt.* [*non* Dawson]

The rocks passed through in this bore from 1,490 ft. to 3,298 ft. are referable to the Staffordian Series. The zoning of this series, as already mentioned, is extremely difficult, but I am inclined to refer provisionally the portion of the bore comprised in the above list, to the Etruria Marl Group.

Among the plants collected from this bore are two, new to Britain—*Samaropsis reniformis* Geinitz sp., at a depth of 1,715 ft., a seed originally described from the Permian, and *Sphenopteris herbacea* Boulay (Le terr. houil. du Nord de la France et ses végétaux fossiles, p. 27, pl. i, fig. 5. 1876), at a depth of 1,768 ft., a species which occurs in the Westphalian of France and Belgium.

Another species, *Neuropteris squarrosæformis* Kidston MS.—not yet described, is also represented by a single specimen which occurred at a depth of 1837—40 ft. It has previously been found in the Blackband Group of the Staffordian Series of Staffordshire and in the Westphalian of Yorkshire. *Holcospermum mamillatum* Lesqx. sp., from a depth of 1,647-1,649 ft., has also previously been met with in the Blackband Group of North Staffordshire, but the record has not yet been published.

Lydden Valley Boring, near Deal, Kent.

Coal Measures entered at 939 ft.

Depth in feet.	
1,505, 1,798	Neuropteris gigantea *Sternb.*
942–945	„ obliqua *Brongn. sp.*
„	„ rarinervis *Bunb.*
1,063	„ scheuchzeri *Hoffm.*
1,792	„ sp.
1,560	Calamites sp.
942-945	Annularia stellata *Schloth. sp.*
1,406, 1,560	Asterophyllites equisetiformis *Schloth. sp.*
942–945	Sphenophyllum emarginatum *Brongn.*
1,063	Sigillaria sp.
1,542½–1,545	Cordaicladus sp.
1,798	Cordaianthus volkmanni *Ett. sp.*

The upper part of this boring from 942 ft. to 1,063 ft., I would refer provisionally to the Blackband Group of the Staffordian Series, and from 1,406 ft. to 1,798 ft. to the Westphalian Series.

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APPENDIX III.

Palæontological Notes on the Donnington Borehole of 1917.

By J. Pringle.

This borehole is described in 'Special Reports on the Mineral Resources of Great Britain,' vol. vii, *Mem. Geol. Survey*, 1918, pp. 39, 40. It was situated on the outcrop of the Tealby Clay, but no cores were obtained until the underlying Claxby Ironstone was reached at a depth of 44 ft.

Claxby Ironstone.—This bed, represented for a thickness of 4 ft., consisted of small brown spherical grains of iron-oxide closely scattered throughout a matrix of pale-brown marl which yielded the following characteristic fossils:—*Lima* (*Plagiostoma*) *subrigida* Roem., *Trigonia ingens* Lycett, and a small fragment of *Crioceras*.

Spilsby Sandstone.—Little of this formation came under observation owing to the failure to draw cores; but sediment-samples obtained between the depths of 48 and 128 ft. were mainly composed of fine and coarse quartz sands. The basement-bed was shown in a core, and proved to be 1 ft. thick. It was highly fossiliferous, containing several indigenous shells in the upper two-thirds, while in the bottom layer, 4 in. thick, numerous rolled black phosphatized casts of fossils and phosphatic nodules were embedded in a dark green matrix of fine quartz-sand. These had evidently been derived from the upper portion of the Kimmeridge Clay.

Amongst the indigenous shells several fragments of an ammonite, obtained immediately above the nodule-bed, appear to belong to a species closely comparable with *Craspedites nodiger* (Eichw.).[1] The fragments are mainly of the outermost whorl, and are ornamented by short well spaced somewhat swollen node-like primary ribs; these give rise to three or more faint narrow secondary ribs which pass over the periphery and unite with the primary ribs on the opposite side. One of the fragments of the outer whorl shows the impression of the secondary ribs on the outer area of the earlier whorl, and the ornament thus preserved, the shape of the whorl, and the degree of involution are in complete agreement with a specimen ascribed by Pavlow to *C. nodiger*, presented by him to the Museum of Practical Geology. *Craspedites subditus* Traut, has been recorded by Lamplugh[2] from the Spilsby Sandstone, and a comparable form from Beds D 4-8 of the Speeton section; but *C. nodiger* differs from this species by its greater thickness, and by the smaller number of primary ribs or nodes. The ammonite-fragments are associated with *Belemnites lateralis* Phill. and *Pecten* (*Syncyclonema*) *orbicularis* J. Sow., and their whitish shells contrast markedly with the black phosphatized casts found in the nodule-bed at the base.

Among the black phosphatized ammonite-casts a well-preserved fragment of a Perisphinctid, 5 centimetres in length, was

[1] E. d'Eichwald. Lethæa Rossica (Period Moyenne), 1866. Atlas pl. xxxvi, fig. 3A, not fig. 3B.

[2] 'On the Speeton Series in Yorkshire and Lincolnshire,' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 200.

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obtained. It is ornamented by a number of strong rounded primary ribs which on bifurcation give rise to two secondary ribs of similar size and strength, and in this respect, as well as in the shape of the whorl, the shell exhibits a close relationship to the specimen figured by Michalski[1] as *Perisphinctes panderi* d'Orb. which he regards as a transitional form from *P. dorsoplanus* Mich. An examination of the suture, which is well shown on the Donnington fragment, affords additional evidence of the close affinity to *P. dorsoplanus*. It is nearly identical with the figure of the suture-line of that species given by Michalski.[2] The Donnington shell also shows a close resemblance to the specimen assigned by Pavlow[3] to *Olcostephanus* (*Virgatites*) cf. *panderi* d'Orb., from Bed E at Speeton. The Speeton shell is abraded through rolling, but it shows somewhat deeper interspaces between the ribs. *P. panderi* occurs numerously in the Virgatites Zone in the neighbourhood of Moscow. This zone includes the narrower zones of *Virgatites miatschkoviensis* and *Perisphinctes pallasianus* in Salfeld's zonal scheme[4] for the Kimmeridge Clay of England; and since the higher of these two, the Pallasianus Zone, is separated from the zone of *Craspedites subditus* by at least six separable zones, we must regard the specimen as a derivative from the Kimmeridge Clay, thus confirming the earlier observations that the Spilsby Sandstone rests unconformably on the Kimmeridge Clay.[5]

Kimmeridge Clay.—The highest beds of this formation passed through in the boring were not represented by cores; but at 159 ft. from the surface, or 30 ft. below the local top of the Kimmeridge Clay, several specimens of a finely ribbed *Perisphinctes* occurred. These shells apparently belong to an undescribed species, and they are identical with or closely related to certain similarly ornamented Perisphinctids which characterise the oil-shale horizon in the upper part of the Virgatites Zone at Kimmeridge. They have also been found in certain bituminous shales at Acre House Mine in Lincolnshire and at Speeton. This wide distribution and restricted vertical range renders these shells important as zonal indices, and, assuming the absence of any abnormal condensation of deposits, their occurrence makes it probable that the highest part of the Kimmeridge Clay existing at Donnington falls within the lower part of the Pallasianus Zone or near the summit of the Virgatites Zone.

Judging from such specimens as it was possible to collect at a time when the cores were not fully available it appears that the zonal sequence is complete. Thus at the depth of 199 ft. the occurrence of specimens of *Gravesia* indicates the Gravesia Zone; at 308 ft. shells referable to *Aulacostephanus eudoxus* (d'Orb.)

[1] A. Michalski. 'Die Ammoniten der unteren Wolga-Stufe.' *Mém. Comité Geol. Russ.*, vol. viii, No. 2, 1894, pl. xii, fig. 1.

[2] Op. cit, pl. xi, fig. 3.

[3] Pavlow and Lamplugh. 'Argiles de Speeton et leur équivalents.' Moscou, 1892, pl. v (ii), fig. 5, and p. 115.

[4] H. Salfeld. 'Certain Upper Jurassic Strata of England,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 423-432.

[5] 'The Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 82.

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were found in association with an apparently new species of *Amoeboceras*, which is closely related to certain forms formerly, though wrongly, referred to *Ammonites kappfi* Opp., from the upper Aulacostephanus Zone of Kimmeridge Bay. Fragments of similar shells were obtained in association with *Exogyra virgula* Defr. in a boring known as Holme No. 1 (unpublished), near King's Lynn, at the depth of about 100 ft.

In addition to the above-mentioned ammonites the following forms were obtained:—

Nodosaria sp.
Lingula ovalis? *J. Sow.*
Orbiculoidea latissima (*J. Sow.*)
Anomia sp.
Corbula sp.
Cyprina sp.
Grammatodon longipunctata (*Blake*)
Grammatodon sp.
Lucina minuscula *Blake*
Ostrea bononiae *Sauvage*
Pecten (Camptonectes) morini *de Lor.*
Protocardia morinica *de Lor.*
Alaria sp.
Fish scales

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APPENDIX IV.

On a Boring for Coal at Winterbourne, Gloucestershire.

By T. C. Cantrill, B.Sc., and B. Smith, M.A.

The northern part of the Bristol Coalfield lying between Cromhall and Mangotsfield takes the form of a syncline with an axis ranging about north-north-east and south-south-west. Its western margin is, however, covered unconformably by the Keuper Marl, under which a part of the Pennant Series and the whole of the Lower Coal Series are hidden from view. With the object of testing the character of these lower divisions of the Coal Measures a boring was commenced in December, 1915, at Winterbourne, 6 miles north-east of Bristol. The results showed that while coals are present, their small number, their poor quality, and their depths are not such as to encourage immediate sinking.

Through the kindness of Mr. R. M. Dillwyn, of Bridgend, Glamorgan, permission was given to the Geological Survey in March, 1918, to visit the borehole and examine the cores. Several marine bands were detected, and numerous fossil plants collected at various depths.

The operations were carried out by Messrs. Vivian's Boring and Exploration Company, Limited, under the management of Mr. Fisher Ray. The total depth attained was 2,338½ ft., most of which was represented by cores.

The Geological Survey Map (Old Series, Sheet 35) shows that the trial was made on the extreme eastern margin of the Keuper Marl, from beneath which the Pennant Grit emerges and extends eastward with a low dip toward the axis of the coalfield. The boring should therefore pass through a few feet of red marl and a considerable thickness of Pennant before reaching the Lower Coal Series. This proved to be the case.

The following is an abstract section of the borehole:—

Boring for Coal on the eastern side of the main road from Bristol to Winterbourne at a point 320 yds. N. of the Bradley Brook Viaduct on the Great Western Railway. New Series one-inch Ordnance Map, Sheet 264 (Bristol); six-inch map, Gloucestershire 68 S.E. Old Series one-inch Geological Map, Sheet 35. Lat. 51° 31′ 5″. Long. 2° 30′ 38″. Height of surface above O.D. about 140 ft.

Boring commenced Dec. 1915, finished Dec. 1917; chiselled to 24 ft. 7 in., continued by shot-boring to 1,575 ft., by diamond-boring to 2,293½ ft., and finished by shot-boring to 2,338½ ft. Diameter of cores, 10½ in. to 2½ in. Dips—at 596 ft., low; at 1,703 ft., 15°; at 2,230 ft., 10°; at 2,254 ft., 5°. Average about 10°.

	Thickness. Ft.	In.	Depth. Ft.	In.
Keuper Marl:—				
Soil	1	0	1	0
Soil and red clay	5	0	6	0
Red clay	5	0	11	0
Coal Measures:—				
Pennant Series:—				
Pennant sandstone, red and grey, with occasional bands of red clay, conglomerate (*e.g.*, at 213 ft.), and films of coal	327	10	338	10
Coal, soft	1	8	340	6
Fireclay with ironstone, and shale	25	0	365	6

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	Thickness. Ft.	In.	Depth Ft.	In.
COAL MEASURES—*cont.*				
Pennant Series—cont.				
Pennant sandstone, grey, with occasional bands of shale, conglomerate, fireclay, ironstone and films of coal	535	0	900	6
Lower Coal Series:—				
Grey pennant sandstone, sandy shales (some red and mottled), ironstones and coarse conglomerates. *Marine Band* at 1,090 ft.	192	6	1,093	0
Coal, soft	–	6	1,093	6
Black shales, dark fireclays, and ironstones	11	3	1,104	9
Coal, bastard	–	3	1,105	0
Fireclays and sandy shales (some red and mottled), pennant sandstones, conglomerates (*e.g.*, at 1,290, 1,302 and 1,443 ft.), and ironstones	338	6	1,443	6
Grey shales, ironstone and fireclays; some red and mottled shales. *Marine Band* at 1488-1494 ft.	160	11	1,604	5
Coal, soft	1	1	1,605	6
Grey shales, fireclays and ironstones ...	127	10	1,733	4
Coal 2 ft. 11 in., black shale 1 in., coal 10 in.	3	10	1,737	2
Black and grey Shales, fireclays and sandstone	16	1	1,753	3
Coal	–	10	1,754	1
Black and grey shales, fireclays, ironstones and sandstones	29	9	1,783	10
Coal	–	6	1,784	4
Grey fireclays, shales and ironstones ...	26	8	1,811	0
Coal	–	10	1,811	10
Grey shales, fireclays, sandstones and ironstones	47	10	1,859	8
Coal, soft, 7 in., dark fireclay 3 ft., coal, soft, 2 ft.	5	7	1,865	3
Grey fireclays, shales, sandstones and ironstones	20	6	1,885	9
Coal	–	6	1,886	3
Grey fireclays, shales and sandstones ...	18	1	1,904	4
Coal and black shale mixed (little being coal)	5	0	1,909	4
Grey fireclay	4	2	1,913	6
Coal	1	10	1,915	4
Shales (some red), fireclays and ironstones; hard siliceous sandstones at 2,036 ft. 9 in. and 2045 ft. 3 in. *Marine Band* at 2,000 ft.	133	2	2,048	6
Coal, 1 ft. 9 in., fireclay 1 ft., coal 4 in., black shale 3 in., coal 3 in.	3	7	2,052	1
Grey fireclay	2	4	2,054	5
Dark grey shale	3	4	2,057	9
Ironstone	–	9	2,058	6
Dark grey shale	3	0	2,061	6
Coal, soft, 1 ft. 3in., fireclay 7 in., coal, soft, 5 in.	2	3	2,063	9
Fireclays, shales and ironstones	11	3	2,075	0
Coal	–	4	2,075	4
Fireclays, shales and ironstones	16	10	2,092	2
Coal	–	2	2,092	4
Fireclays, shales, ironstones and sandstones	22	11	2,115	3
Coal	–	6	2,115	9
Shales, fireclays and ironstones	50	11	2,166	8
Coal	–	4	2,167	0

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	Thickness. Ft.	In.	Depth. Ft.	In.
COAL MEASURES—*cont.*				
Lower Coal Series—cont.				
Shales, fireclays and ironstones	73	10	2,240	10
Coal, 10 in., black shale and coal mixed, 8 ft., coal 3 ft.	11	10	2,252	8
Shales, fireclays and ironstones	9	10	2,262	6
Coal, inferior, 1 ft. 3 in., black shale and coal mixed, 7 in.	1	10	2,264	4
Shales, fireclays and ironstones, with siliceous sandstones from 2,289 to 2,294 ft. 9 in.	72	8	2,337	0
Loss	1	6	2,338	6

Correcting for a dip of 10°, the total thickness proved is 2,303 ft.

In the above abstract, all the coals are given, though the intermediate beds are summarized. The base of the Pennant Series has been placed at 900 ft. 6 ins., for below this depth pennant-like sandstones, though they are recorded, are subordinate to argillaceous types of sediment. Towards the top the sandstones in the Pennant Series are red, presumably through staining from the Keuper. This reddening extends to a distance of 131 ft. below the base of the Keuper, though red joints are recorded as low as 320 ft. below that base. The red and mottled shales that appear here and there, often at long intervals, in the Lower Coal Series between the depths (from surface) of 912 ft. and 2,121 ft., no doubt owe their colour to contemporaneous causes, and not to Triassic staining.

Specimens of the occasional thin bands of conglomerate in the Pennant Series and the Lower Coal Series were collected for detailed examination. One band, measuring, with interbedded pennant, 5 ft. 6 ins., at 213 ft., consists of subangular and subrounded fragments of vein-quartz and felsites in a sandy matrix. The fragments range up to 15 mm. in diameter.

Three bands from the Lower Coal Series, each a few feet thick, from depths of 1,290, 1,302, and 1,443 ft., closely resemble each other except in the size of the fragments. In the hand-specimens they are characterized by the variety of colour exhibited by the fragments, which are green, pale pink, red, brown, grey, and white.

Dr. Thomas reports the result of his microscopic examination of these conglomerates as follows:—

"E. 11874–11877.—The specimens collected from this boring at 213, 1,290 1,302 and 1,443 ft. from the surface are similar and consist of conglomeratic grits of moderately coarse texture.

"The pebbles and fragments are not completely rounded and in some cases are subangular. They are variously coloured pink, grey, and green, and are for the most part fine-textured rocks. Quartz both transparent and milky occurs as pebbles and appears to be derived in some cases from vein-material and in others from granitic or other igneous rocks. The matrix is moderately coarse grained and sandy and has a buff to grey colour.

"Microscopically the main features that are brought out are the following—Quartzite, sheared and strained, forms a considerable proportion of the pebbles. Other rocks represented are ceratophyric in character and range from devitrified soda rhyolites through microporphyritic ceratophyres to coarser rocks that approach albite granites in composition and texture. Clastic rocks other than quartzites are represented by a relatively small number of fragments of felspathic sandstones and silicified pyroclastic rocks and hornstones.

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"The whole assemblage of pebbles and the general nature of the rock suggests derivation from rocks of considerable antiquity which had been subjected to earth-movement. An ancient Pre-Cambrian ridge similar to that of St. Davids in which albite-bearing rocks are well represented would give rise to conglomerates or arkoses of this character. The probability of the St. Davids area having furnished any of the material is somewhat remote."

Many of the 'grey shales' in the Lower Coal Series would be better described as greenish-grey clunches or mudstones. Some of the shales, fireclays, and clunches contain bands of sphaerosiderite; samples were collected at 2,021 ft. and 2,172 ft., and occurrences noted at about ten other depths. Many of the fireclays look promising from an economic point of view. The numerous ironstone-bands are of the usual coal-measure type—argillaceous carbonate in the form of nodules.

Abundant plant-remains occur in the Lower Coal Series, but are somewhat restricted in their distribution; great thicknesses of greenish-grey clunches proving entirely barren. Sixty samples were collected. Mollusca, which were specially sought for, were found at 6 different depths and 147 specimens were collected. Beside *Carbonicola*, *Schellwienella* and other marine forms have been identified. The marine bands, which are characterized by dark-grey or black smooth mudstone or soapy shale, were found at the depths of 1,090, 1,488-1,494, and 2,000 ft. The apparent association of marine and freshwater shells at the depths of 1,090 ft. and 2,000 ft. is probably due in each case to an alternation of conditions, rather than to an actual mixture of the two faunas. Other bands of similar lithological type were observed at 1,082 ft. and 1,731 ft., but these yielded less definite remains. The identification of the fossils by Mr. John Pringle is as follows:—

PLANTÆ.

	Depths in feet.
Alethopteris lonchitica (*Schloth.*)	2,220.
Linopteris obliqua (*Bunb.*)	1,200, 1,343.
Neuropteris heterophylla *Brongn.*	2,130, 2,220, 2,280.
Pecopteris miltoni (*Artis*)	1,200.
„ sp.	1,200.
Sphenopteris *cf.* elegans *Brongn.*	2,160.
„ *cf.* trifoliata (*Artis*)	2,121, 2,131.
„ sp.	1,200.
Calamites sp.	1,200, 2,231.
Asterophyllites equisetiformis (*Schloth.*)	1,200, 1,258.
„ sp.	1,200.
Sphenophyllum cuneifolium (*Sternb.*)	1,809.
Palaeostachya sp.	1,809.
Lepidophyllum minus *Goode*	1,090.
Cordaites principalis (*Germar*)	1,200, 2,130.
„ sp.	2,191.

ANIMALIA.

MARINE.

	Depths in feet.
Crinoidal remains	2,000
Ambocoelia carbonaria *Hind*	2,000
„ ?	1,090
Cf. Chonetes hardrensis *Phill.*	2,000
Chonetes *cf.* laguessiana *de Kon.*	2,000
Lingula mytiloides *J. Sow.*	1,491, 2,000
Productus sp.	1,490, 2,000

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ANIMALIA—*cont.*

MARINE—*cont.*

	Depths in feet.
Schellwienella *cf.* crenistria (*Phill.*)	1,494
Nucula ?	1,490, 2,000
Nuculana *cf.* attenuata (*Flem.*)	2,000
Schizodus *cf.* antiquus *Hind*	2,000
Raphistoma ?	2,000
Glyphioceras ?	2,000
Orthoceras sp.	2,000
FRESHWATER.	
Anthracomya minima (*Ludwig*)...	About 1,090
„ sp.	1,090
Carbonicola sp. [cf. *Carbonicola robusta* J. Sow.]	1,485
Naiadites *cf.* carinata *J. Sow.*	About 2,000
„ sp.	2,000

The boring shows that there is only one thin coal in the lower 889 ft. of the Pennant Series, and (ignoring seams not exceeding 12 ins. in thickness) only nine in the upper 1,438 ft. of the Lower Coal Series. Some of these coals are soft, or thin, or interbedded or intermixed with shale. But the boring did not penetrate the whole of the Lower Series, and further seams may exist at greater depths. Little is known about this western side of the Gloucestershire coalfield, and the boring does not yield sufficient new data by which a correlation can be made with the measures on the eastern side.

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APPENDIX V.

On a boring at Abbey Mills, Holywell, 1917-18.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S.

This boring was made by Mr. A. Timmins, A.M.I.C.E., F.G.S., and we are indebted to him for much of the information concerning it. A shaft was sunk to a depth of 12 ft. within the grounds of the Abbey Mills, at a height of 50 ft. above O.D. and the borehole was made in the bottom of the shaft. The diameter of the hole at the lowest point reached was 6 in. The boring was made in search of water but was not successful. No cores were preserved down to a depth of about 115 ft., and for that part of the record (printed below in italics) we are indebted to Mr. Timmins. For the remainder of the hole a nearly continuous series of cores had been preserved. These were examined by Mr. Pringle, upon whose identification the following account is based, apart from some notes in brackets which relate to specimens sent up to this office by Mr. Timmins during the progress of operations:—

	Thickness. Ft.	In.	Depth. Ft.	In
Superficial Deposits [Glacial]				
Gravel	16	–		
Reddish boulder-clay	32	–		
Yellow and greenish clay	15	–		
Blue silty clay	7	–	70	–
Middle Coal Measures:—				
Grey shales	14	–	84	–
Black shales with thin sandstones and thin coals	3	–	87	–
Grey shales	14	6	101	6
Grey grit	7	–	108	6
Black shale	1	–	109	6
Soft blue shale	2	–	111	6
Lower Coal Measures (Gwespyr Sandstone and Holywell Shales:—				
Grey micaceous laminated sandstones, bedding-planes sharply puckered at 128 ft.	37	6	149	–
Dark-grey sandy shales with thin ribs of sandstone. Plant-fragments numerous	7	–	156	–
Black greasy shales with two hard bands; marine fossils abundant about the depth of 175 ft.	32	–	188	–
White and grey fine-grained sandstones, laminated in places with numerous badly preserved plant-remains at 208 ft.	36	–	224	–
Soft grey sandy shales	14	–	238	–
Dark-grey and grey shaly sandstone with beds of hard sandstone	41	–	279	–
Soft grey sandy shales, with two beds of sandstone	62	6	341	6
Grey shaly sandstone	62	6	404	–
Soft dark-grey sandy shales with *Mariopteris*	21	–	425	–
Fine-grained whitish-grey sandstone	5	–	430	–
Dark-grey sandy shales	12	–	442	–
Fine-grained grey laminated sandstone	20	–	462	–
Soft dark-grey sandy shales	21	–	483	–
Black shales with two dark compact earthy limestones. Goniatites numerous between the depths of 545 ft. and 550 ft.	70	–	553	–
Soft pyritous sandstone with *Stigmaria*	3	–	556	–
Fine-grained white sandstones, micaceous in places, with some dark-grey shaly bands	28	6	584	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
Lower Coal Measures—*cont.*				
Soft dark-grey micaceous sandstones passing below into dark sandy shales with ribs of sandstone	62	3	646	9
Fine-grained whitish-grey laminated sandstones alternating with dark-grey sandy micaceous bands of shale	95	3	742	–
Black and dark-grey shales, becoming hard and splintery below, with several bands of dark compact earthy limestone (cement-stone), varying in thickness from 4 in. to 20 in. Marine shells abundant	198	–	940	–
Black compact earthy limestone (cement-stone), traversed by narrow veins of calcite	5	–	945	–
Fault-rock :—				
Thin-bedded black chert, brecciated and veined with calcite; with galena and specks of copper-pyrites and iron-pyrites	43	–	988	–
Greyish-white crinoidal limestones, silicified in places, with thin layers of black chert in uppermost beds. Limestones coarser in texture near base, and containing numerous grains of quartz; a small lump of galena at 988 ft. (A specimen from 991 ft. consisted of coarsely crystalline brown limestone with films of shale; one from 1,018 ft., of bituminous limestone with black shale filling a vertical fissure; a third from 1,025 ft. contained flakes and fragments of black shale. All three rich in crinoids. Specimens from 1,034 and 1,042 ft. were crinoidal limestones, partly altered into black crinoidal chert)	57	–	1,045	–
Black cherty limestones with a 2 ft. band of grey limestone at 1,057 ft., all veined with calcite. (A specimen from 1,052 ft. consisted of black chert with calcite-joints; one from 1,070 consisted of black chert and black shale similarly veined; another from 1,087 showed a breccia of chert and shale cemented by calcite, and a fourth from 1,090½ ft. consisted of brown bituminous limestone)	46	–	1,091	–
Thin-bedded grey and dark-grey limestones with numerous black shaly partings. (A specimen at 1,092 ft. showed coarsely crystalline limestone enclosing angular fragments of black shale, and another at 1,096 consisted of bedded black shale and limestone, dipping at 28°)	83	–	1,174	–
Grey sandy limestones; *Productus sp.* abundant ...	20	–	1,194	–

From these and the observations made by Mr. Timmins the dip appears to have been from 15° to 29° to a depth of 600 ft., 29° at 735 ft., 40° from 900 ft., 15° to 17° at 998 ft., 28° at 1,096 ft , and 40° at 1,111 ft.

The boring was situated near the margin of an area where the Middle Coal Measures are believed to underlie the Glacial Deposits, and the grey and black shales, 41½ ft. thick, first encountered, may be attributed to that sub-division. Below these the sandstone worked in the Gwespyr Quarries might be expected, and, as a fact, the sandstone 37½ ft. thick was found by Mr. Pringle closely to resemble the rock of the quarries, a peculiar puckering of the bedding-planes being noticeable in both. As a sub-division, however, the Gwespyr Sandstone, southwards from Gwespyr, becomes increasingly difficult to separate from

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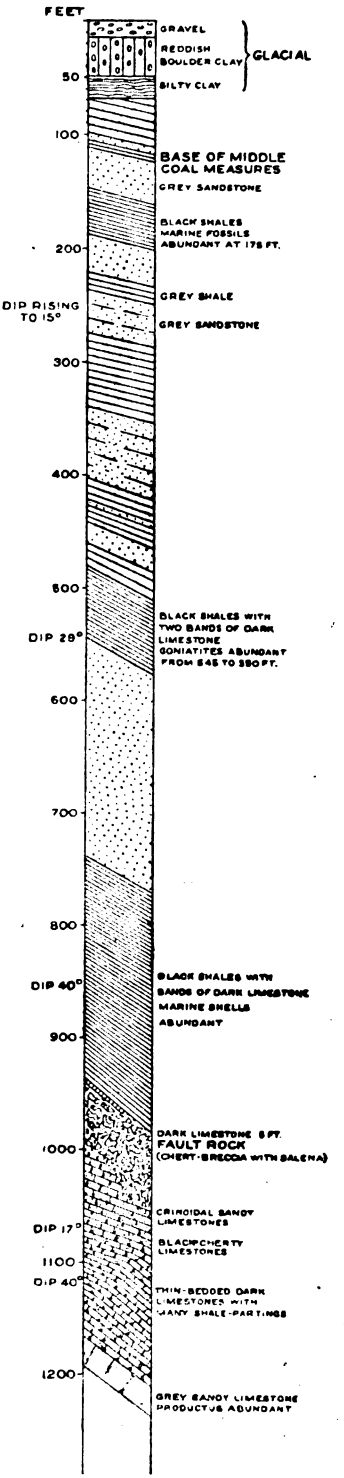
FIG. 3.—SECTION OF THE ABBEY MILLS BOREHOLE, HOLYWELL.



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the underlying Holywell Shales. There is no definite distinction possible into a sandstone- and a shale-group; the two types alternate, and in the borehole fossiliferous shales, as usual black and associated with black argillaceous limestones, occur at the top, the middle and the bottom of the series. Nor is any distinction possible between the fauna of a fossiliferous shale in what has been called the Gwespyr Sandstone and that of a fossiliferous band in the Holywell Shales. The two sub-divisions therefore have been grouped together in the record of the borehole. The length of core assignable to them amounts to 833½ ft., and if correction be made for the dip, the actual thickness may be taken as about 750 ft. It may be noted that light-coloured highly calcareous sandstones occurred at depths of 121 and 139 ft.

That the black limestones at and a little above the depth of 945 ft. correspond to the cement-stones which were once worked in Coed Llwybr-y-bi[1] admits of little doubt. They closely resemble them and occur at the same horizon.

The marine fossils found at depths of 175 ft. and 940 ft. include *Pterinopecten papyraceus* (J. Sow.), *Posidoniella laevis* (Brown), *Glyphioceras reticulatum* (Phill.) and *Glyphioceras sp.*, as determined by Mr. Pringle.

The Chert Beds should have been reached in a short distance below the cement-stones, but it was noticeable that the dip increased rapidly in the lower part of the shales, and that the ground from 945 ft. downwards consisted mainly of fault-rock. The cores broke away in fragments which revolved with the boring tool. One of the lumps thus produced at a depth of 959 ft. may be described as a breccia of black chert and shale with a good deal of galena, specks of copper-pyrites and ribs of calcite. At 970 ft. the boring was reported by Mr. Timmins to be still in fault-rock with galena, and down to 1,087 ft. there were indications of fissuring and of reconstruction. For the last 100 ft. the hole seems to have been clear of the fault and to have traversed some of the higher limestones which crop out on Halkin Mountain. No beds resembling the Black Limestone of Halkin Mountain were recognised, though these form a distinct sub-division at the nearest outcrop. They are impersistent, however, and their absence may be due to this fact, or to their having been cut out by the fault.

As an attempt to obtain water the borehole was a failure, but it has much significance in other respects. The bodies of galena which have been so prolific on Halkin Mountain occur in veins, but tend to follow the intersection of a vein with certain strata. Much ore was got in the Chert Beds, and 'runs' of ore followed, more or less closely, certain beds in the limestone-series, the ore-bodies in a general way dipping eastwards with the strata. The old workings were carried to the bottom of these productive beds under Halkin Mountain, and failure to find ore at greater depths vertically led to a belief that deep mining was useless in Flintshire. The ore-bodies however could not be followed far

[1] 'The Geology of the Neighbourhoods of Flint, Mold and Ruthin,' *Mem. Geol. Survey*, 1890, p. 65.

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down their inclination eastwards, and there remains a possible but unproved lead-field under the cover of Coal Measures in that direction.

The profound influence exercised by shales upon the distribution of the ores, was emphasised in the Memoir descriptive of this district. "The deposition of the ore seems to have been governed not only by the Holywell Shales, but even by the thin bands of shale which occur in the upper part of the limestone; for though in the northern part of the county the ores have generally clustered most thickly under the Holywell Shales, yet in several instances veins, not rich in other parts, have yielded ore immediately below thin bands of shale in the limestone. . . . The influence of the shales on the distribution of the ores seems to have been partly due to their having acted as water-tight blankets, checking the flow of underground water, which must have been eastwards ever since the rocks acquired their present easterly dip. But the precipitation also of the ores of lead and zinc was probably directly due to the giving off of sulphuretted hydrogen during the decomposition of pyrites in the shale."[1] It was clear, therefore, that there existed a possibility that the chert and limestone which underlie the Coal Measures might prove to contain productive veins. The Abbey Mills boring is the first exploration that furnishes evidence on this point.

That the boring passed through a fault is certain, and that the fault belongs to the north-and-south system is probable, for all the faults proved, or inferred to exist, in the neighbourhood of the hole, belong to that system. The existence of specks of copper-pyrites in the fault-rock support the hypothesis, for that ore frequently occurs in the north-and-south cross-courses of Halkin Mountain, but is exceptional in the east-and-west veins.[2] It is open to doubt, however, whether the fault is a downthrow east or west. A fault inferred to exist on surface-evidence, and throwing down to the east, is shown on the Geological Map Flint 6 N.W. It would pass, if it continued, about 100-150 yards west of the borehole, but at this point such evidence as exists is suggestive of a westerly downthrow, and, as a fact, a westerly downthrow of 150 yards has been proved in the Englefield Colliery (about a quarter of a mile farther north) to range towards the same point.

[1] 'The Geology of the Neighbourhoods of Flint, Mold and Ruthin,' *Mem. Geol. Survey*, 1890, pp. 161–2.

[2] *Op cit.*, p. 198.

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APPENDIX VI.

On a Boring at Kilnsea, Holderness.

By G. W. Lamplugh, F.R.S.

One-inch Ord. Map (N.S.), Sheet 81.82. One-inch Geological Map (Old Series), Sheet 85.

The boring was made for the War Office in 1916-17 to obtain water, but the results were disappointing. The site is ⅓ mile N.E. of Kilnsea Church, at 25 ft. above O.D., on the neck of land between the Humber and the open sea.

The boring has two features of particular interest: (1) it is the deepest yet made in Holderness; and (2) it is at the most easterly place that a boring could be put down on land north of the Humber. The depth attained was 1,001 ft., and the only other boring in Holderness approaching this depth was one made at Hornsea in 1862-4, which is stated to have gone to 978 ft. in chalk and to have ended in 'black warp or clay,'[1] but the record is unsatisfactory.

The log of the Kilnsea Boring, as supplied to us, is as follows:—

	Thickness, ft.	Depth, ft.
Red marly clay	10	10
Blue „ „	51	61
Silt	2	63
Boulder clay	64	127
Silt	3	130
Chalk	40	170
Soft chalk	468	638
Hard chalk without flints	363	1,001

Brackish water met with up to 800 ft. No water at 900 ft. Brackish water at 1,000 ft., and 3½ gallons per hour in quantity.

A set of specimens was sent for our inspection when the boring was finished, and those from the drift yielded a little further information, as set forth below, but those from the Chalk (at intervals of every 25 ft. or so) had all been pugged into the condition of whiting and showed hardly any difference from top to bottom. A search was made for chips of flint, but none was found, which leads to the conclusion that the Chalk with Flints was not reached, and that the Chalk without Flints may be more than 850 ft. thick in this part of Holderness. At Flamborough Head the Chalk with Flints, the Lower Chalk, and the Red Chalk, together, have a thickness of about 620 ft.,[2] so that if this thickness is continued under Holderness, the whole Chalk formation is likely to be not less than 1,500 ft. thick in the neighbourhood of Spurn Point.

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[1] 'The Water Supply of the East Riding of Yorkshire,' *Mem. Geol. Survey*, 1906, p. 106.

[2] For notes on the thickness of the chalk in Yorkshire *see* Lamplugh, *Proc. Yorks. Geol. and Polytech. Soc.* N.S., vol. xiii (1895), p. 75.

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The following are our observations on the specimens:—

From depth of— Ft.	
10	Weathered reddish boulder-clay (resembling 'Hessle-Clay' of cliff-sections).
25	Purple boulder-clay, containing many fragments of chalk.
61	Purple-brown boulder-clay, with crumbs of chalk.
63	" " rather sandy, with a 1½ in. pebble of chalk.
88 and 102 ...	Firm rather sandy darkish purple boulder-clay, with crumbs of chalk; (these and the preceding specimen probably represent the 'Basement Clay' of the coast section).
122	Brownish purple boulder-clay, streaky; (probably some laminated clay pugged among it).
127	Chocolate brown silty clay; no stones.
130	Brown laminated silty sand, with particles of mica and specks of carbonaceous matter.
137	Firm small chalk-rubble ('chalk-wash') mixed with grit; contains a ¼ in. cherty pebble; (like the 'chalk-wash' locally occurring at base of drift on Flamborough Head).
162 to 1,000 ...	Pugged chalk, reduced to powder-paste, smooth and gritless, with here and there a small pellet of dark grey marl (indicating occasional marl partings).

The noteworthy points respecting the drifts, so far as they are represented by the specimens, is the preponderance of boulder-clay; the lack of marked diversity in its composition; the apparent absence of interbedded sand or gravel which is usually abundant in the Holderness cliff-sections; and the presence of fine chalky rubble between the Chalk and the drift. This Chalk-rubble is recorded as part of the Chalk in the log of the boring, but the specimen from the depth of 137 ft. was unmistakably a gritty rubble or 'Chalk-wash,' and not the solid Chalk. As to the thickness of this deposit, the only evidence is that the depth assigned to the specimen is 7 ft. below the supposed top of the 'Chalk,' and that the next specimen, from a depth of 162 ft. is pulverized Chalk evidently representing the solid rock. The thickness of the rubble is therefore more than 7 ft. and less than 32 ft., but no closer approximation is practicable. A similar rubble exposed in the cliff and foreshore at Sewerby, on the south side of Flamborough Head, was found to contain small land-shells, indicating that it had been accumulated on a land-surface.[1] The presence of similar material at Kilnsea at over 100 ft. below sea-level suggests a minimum measure for the elevation of the land above sea level in East Yorkshire prior to the glaciation. The laminated clay and sand between the chalk-rubble and the boulder-clay recalls the presence of similar deposits in the same position in some of the drift-filled valleys of Flamborough Head, *e.g.*, that known as Dane's Dyke. The supposed Interglacial Shelly Gravels of Kelsey Hill and other places in the interior of Holderness appear to have no representative in the section.

[1] Lamplugh. *Proc. Yorks. Geol. and Polytech. Soc.* N.S. vol. xv (1903), pp. 91–5.

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APPENDIX VII.

Further Note on the Boring at Gosmore.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S.

In the description of this boring given in the 'Summary of Progress for 1917,' p. 46, reference to a previous boring was accidentally omitted. A boring made at a point about 300 yards N.N.W. of Thistley Farm was described by the late W. Hill in *Proc. Geol. Assoc.*, vol xxiii, 1912, p. 121. It was carried to a depth of 200 ft. and failed to reach the base of the glacial drift. The boring described in the Summary of Progress was situated about 660 yards N.N.W. of Thistley Farm, and was made in 1917. A comparison of the two records shows that the drifts passed through differ in detail; the beds of sand, gravel and boulder-clay are clearly liable to variation. The earlier boring failed to furnish a supply of water.

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247. SWANSEA	1 6	1 6	2 6
248. PONTYPRIDD	1 6	1 6	3 6
249. NEWPORT (Mon.)... ...	1 6	1 6	1 6
254. HENLEY-ON-THAMES ..	—	1 6	2 0
261-2. BRIDGEND	1 6	1 6	1 6
263. CARDIFF	1 6	1 6	2 0
267. HUNGERFORD and NEWBURY	—	1 6	2 6
268. READING	6 9	1 6	1 6
269. WINDSOR	—	—	2 6
282. DEVIZES	—	1 6	1 0
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284. BASINGSTOKE	—	1 6	2 0
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335. TREVOSE HEAD... ...	—	1 6	2
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347. BODMIN and ST. AUSTELL	—	1 6	4
348. PLYMOUTH and LISKEARD	—	1 6	1
349. IVYBRIDGE	—	1 6	3
350. TORQUAY	—	1 6	2
351 and 358. LAND'S END DISTRICT...	—	2 6	2
352. FALMOUTH and TRURO	—	1 6	7
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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1919.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1919.

I.—INTRODUCTION.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., Director.

The expectation expressed in the Summary for 1918 that the normal work of the Geological Survey might soon be resumed was realised in 1919. A part of the series of Special Reports on the Mineral Resources of Great Britain still awaited completion, and some members of the staff were engaged upon memoirs on iron, lead, zinc, copper, arsenic and antimony, oil and salt in continuation of that series. The work, however, which had been in hand in the early stages of the war was resumed in the Denbighshire and Shropshire district (now more suitably described as the Montgomeryshire and Shropshire district), and the Warwickshire and Staffordshire district. Further work in the London and South-eastern district was postponed for the present.

In the Montgomeryshire and Shropshire district the mapping of the pre-Cambrian rocks of the Shrewsbury neighbourhood has been commenced, and that of the Ordovician has been completed so far as regards the sheets of the one-inch map in hand. A separation of the Ordovician into Caradocian and Ashgillian in accordance with the classification advocated by Prof. Marr has been adopted. The Ashgillian is difficult to distinguish from the overlying Llandovery mudstones by lithological character, but the occurrence of *Pentamerus* in the latter determines their Silurian age. The lower Llandovery beds alone appear to be present, and a gap in the sequence between them and the Tarannon is suspected. The Wenlock and Ludlow are well developed and a precise boundary might be drawn between them on palæontological evidence, but by an expenditure of time which has not been possible.

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The so-called Permian rocks between Wellington and Newport are now relegated to the Keele Beds. They appear to be faulted against the Bunter, but the boundary is obscured. The Glacial deposits are both of local and distant origin. The boulders, which include fragments of marine shells, have been derived partly from northern sources, such as the bed of the Irish Sea and the Lake District, and partly from the neighbouring parts of Wales. Expanses of Late Glacial gravels, at low levels, featureless save for recent river-bluffs, are a characteristic of the neighbourhood, as well as conspicuous developments of the hummocky form so often assumed by Glacial sands and gravels.

In the Warwickshire and Staffordshire district, the small inlier of Silurian rocks, first recognised as such by Mr. Wickham King, has been investigated. For the rest, the work lay principally in the visible coalfield of South Staffordshire and its surroundings. The selection of a line for the base of the Upper Coal Measures required much consideration, and eventually the base of the lowest coarse grit, a distinctive rock above the highest workable coal, was chosen. Good progress was made in mapping the barren upper measures, and the Triassic rocks west of the South Staffordshire Coalfield. The highly important explorations by borings and shafts to the west of the boundary-fault of the coalfield have been kept under continuous observation.

The Glacial deposits completely mask the surface and determine the nature of the soil. They consist of sands and clays with few boulders, all of western origin.

The deep borings that were being made in 1919 to prove the eastern extension of the Nottinghamshire coalfield have been systematically visited, and full particulars have been obtained.

In Scotland also the return of Geologists who had been on active service rendered some field-work possible. The Carboniferous rocks of Ayrshire and Renfrewshire in the neighbourhood of Paisley, Beith and Dunlop were revised by Mr. E. B. Bailey and Mr. J. E. Richey. Most of the district mapped consisted of lavas on the margin of the coalfields. The volcanic rocks are principally basalts of the Dalmeny, Dunsappie and Markle types, but mugearites, trachytes and keratophyres also occur. Old volcanic orifices occupied by masses of trachyte, gabbro and basalt, penetrate the lavas of the plateau; one of them is noteworthy as showing 'ring-structure.' Mr. E. M. Anderson spent a short time on the revision of the Coal Measure areas around Troon and Galston. Mr. Macgregor collected much new information from bores which are being put down in the Douglas coalfield.

In the Highlands, Mr. H. H. Read continued the revision of the Portsoy, Huntly and Insch districts of Banffshire and Aberdeenshire. In that country there is a remarkable series of plutonic igneous rocks ranging from granite to peridotite, exceptionally varied in character and presenting many interesting petrological problems. The exposures of the Highland schists, especially in the coast-section from Buckie to Gamrie, are deserving of careful study.

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Recent Borings for Oil.

The eleven borings that were being made or are in contemplation by Petroleum Development Managers, acting under His Majesty's Petroleum Executive, reached a significant stage by the close of the year. Seven are situated in Derbyshire, two in North Staffordshire and two in Scotland. The results are described on pp. 22-23, 41-43.[1] At present the Hardstoft boring has alone yielded oil in notable quantity. The amount stored at the end of 1919 amounted to 1,900 barrels.

In other borings the strata which yield oil at Hardstoft have proved unproductive.

In addition, oil has been accidentally discovered in a boring at Retford made in search of coal. It was met at a depth of 3,003 ft. in sufficient amount to justify the plugging-up of the hole with a view to conserving the oil for further investigation. Boring operations for oil at Kelham[2] had not been commenced by the end of the year.

II.—FIELD WORK.

(A)—England and Wales.

(1) Montgomeryshire and Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.

B. Smith, M.A.
R. W. Pocock, B.Sc.
W. B. R. King, B.A., O.B.E. } Geologists.

During the past season the mapping of a small area between Llansantffraid-ym-Mechain and Llanfyllin in Montgomeryshire by Mr. Smith and Mr. King has completed the survey of the Oswestry Sheet (137) of the one-inch map.

In the Wem Sheet (138) a belt of country from near Ellesmere eastward to beyond Wem has been mapped by Mr. Pocock. Along the southern border of the sheet and on the northern margin of the Shrewsbury Sheet (152) the work, where suspended at the close of 1915 between Shrewsbury and Wellington, has been taken up by Mr. Cantrill, who has carried the mapping eastward as far as the eastern margins of both sheets.

PRE-CAMBRIAN.

The Uriconian rocks of Wrockwardine are found by Mr. Cantrill to consist of red and purple rhyolites, in places showing fluxion and spherulitic structures. Occasional beds of agglomerate and tuff are present, and some basic intrusions have been noted. The rocks extend under the Glacial drift as far as Admaston, where they are cut through by the Shrewsbury and Wellington railway.

[1] The history and results of the exploration are more fully set out in 'Special Reports on the Mineral Resources of Great Britain,' vol. vii, Mineral Oils, &c. *Mem. Geol. Surv.*, 2nd ed., in the press.

[2] Near the site of the boring described in the 'Summary of Progress for 1917,' *Mem. Geol. Surv.*, 1918, pp. 48–50.

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ORDOVICIAN.

The subdivision of the Bala beds into two stages, viz., Caradocian and Ashgillian, as mentioned in the *Summary* for 1915 (p. 5), has been applied by Mr. King in the Llanfyllin area.

The Caradocian stage consists of sandy mudstones with fine-grained muddy sandstones, one of which, a ripple-marked band somewhere near the middle of the stage, attains a thickness of 10 ft.

The lower portion of the stage is rather poor in organic remains, but in the higher beds fossils became more abundant. These generally consist of brachiopods (*Orthis elegantula* and *O. alternata*), trilobites (*Asaphus*, *Calymene*, and *Trinucleus* of the *concentricus* type) and lamellibranchs.

Near the top of the stage the beds become more calcareous, and lenticular bands of limestone come in, while the arenaceous beds appear to grow ashy. In a few localities where the beds are well exposed (*e.g.*, at Lluest quarry, a mile south of Llanfyllin), thin bands made of fragments of felspars, etc., are to be seen interbedded with the sandy ash-beds and lenticular limestones. These beds contain fossils that resemble those in the sandy mudstones below, although in the quarries at Bwlch-y-cibau certain bands are crowded with large beautifully-preserved specimens of *Strophomena*, which are less abundant in the lower beds.

In the area south and south-east of Llansantffraid-ym-Mechain, mapped by Mr. Smith, the higher part of the Caradocian consists of sandstones and shales with poor cleavage, overlain by black shales with thin bands of limestone.

The sandstone group, where typically developed, consists of tough blue micaceous and laminated sandstones or fine grits, up to 1 ft. in thickness, with interbedded thin shales and sandy mudstones, the softer beds being cleaved. They are characterised in this area by the inclusion of some beds of rather platy fine-grained sandstone of a compact silty nature, traversed by narrowly-spaced strike-joints at right-angles to the bedding. In some of the slightly calcareous beds fossils characteristic of the Caradocian are abundant.

The fine ash and lenticular limestones of the Llanfyllin district pass up into massive grey rather impure limestones. These are well exposed in the Lluest dingle, and appear to be identical with those to be seen in the quarry at Pen-y-garnedd, and which we propose to call the Pen-y-garnedd Limestone. At Bwlch-y-cibau the limestone is reported to have been burnt for lime, and both here and at the quarry near Greenhall these strata contain *Orthis actoniae*.

The phosphate-bed that occurs between the limestone and the overlying graptolitic black shales is not now exposed, although an adit near Greenhall quarry is said to have reached it. At several localities the black shales have yielded graptolites, generally in poor condition except at Pen-y-garnedd quarry, where the section has been opened up and cleared during the war. Some well-preserved specimens collected here have been identified by Miss

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G. L. Elles, D.Sc., F.G.S., who visited the more important sections of the limestone and shales. They[1] prove to be various species of *Orthograptus*. The exact horizon of these shales has, however, not yet been definitely fixed; but from a preliminary study of the graptolites Miss Elles assigns them to the *Diplograptus pristis* zone of Sweden, which is correlated with the highest Caradocian of Britain. The shales, therefore, are a graptolitic facies of a part of the sequence usually represented in this country either by calcareous or arenaceous beds (as at Bala and in Carmarthenshire and Shropshire), or by barren mudstones (as in the Southern Uplands of Scotland).

South and south-east of Llansantffraid the Caradocian beds mapped by Mr. Smith are surmounted by the Pen-y-garnedd black shale group, which has a thickness ranging up to about 100 ft. The shales contain thin bands of crinoidal limestone, the thickest seen measuring no more than a few inches.

In the shales small brachiopods, but no graptolites, have been discovered. They are exposed in a wood (where they are said to have been dug formerly in search of coal) about 400 yards E.S.E. of Vyrnwy Bank Farm, 1½ miles E.N.E. of Llansantffraid. Other exposures occur at Dingle, about half-a-mile farther south. The beds appear to be referable to much the same horizon as the Gwern-y-brain group[2] of the Welshpool District.

The realization on more detailed mapping that the black shales may replace part or nearly the whole of the limestone-group enables us to account for their varying thickness, which was formerly[3] attributed to unconformity between the Caradocian and the Ashgillian stages. This appearance of discordance seems also to have been due at some localities to strike-faulting, which would naturally follow the strike of the soft shales. In no exposure has the Ashgillian been seen to be unconformable to the black shales.

The Ashgillian strata in Mr. King's district near Llanfyllin consist in their lower part of soft green-grey mudstones, with spots and blotches of a darker blue-grey colour. Bedding is not well developed, although, in a few places near the base, nodules, presumably rather more calcareous than the rest of the rocks, are present along bedding-planes. The fossil-contents consist mainly of trilobites and small brachiopods of the species usually met with in the lower part of the Ashgillian in Wales.

The middle and upper parts of the Ashgillian stage tend to become gradually more sandy, although the grains of sand are always extremely fine. Towards the top of the stage, thin siliceous bands come in, and the strata, although retaining their grey-green colour, grow more shaly and sandy, and less like mudstones. The beds are fossiliferous throughout; but it is only in certain bands in the middle and upper portions that fossils occur in any abundance.

[1] Previously some poor specimens had been identified as *Mesograptus multidens*. 'Summary of Progress for 1915,' p. 5.

[2] A. Wade, 'The Llandovery and Associated Rocks of North-Eastern Montgomeryshire,' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, pp. 428–431.

[3] 'Summary of Progress for 1915,' p. 5.

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South of Llansantffraid, in the ground mapped by Mr. Smith, the Ashgillian Beds occupy the centre of a broad synclinorium of folded Caradocian Beds, its central axis lying slightly oblique to the course of the river Vyrnwy.

The strata consist chiefly of greyish-green or blue to brown mudstones, occasionally with sandy lamellæ. Some of the beds are spotted and blotched by little inclusions of a dark-blue tint, recalling the speckled Llandovery beds of the Mynydd-Cricor and Glyn districts in the Llangollen area. In places they are calcareous and contain sandy and calcareous nodules arranged along the dip, with their flat sides at right angles to the bedding. The calcareous nodules occasionally resemble smooth cement-stones, and may form thin beds of limestone. These rocks are richly fossiliferous.

They are overlain by a belt of thin limestones with interbedded ashy shales, well exposed in a quarry 200 yards N.N.W. of Gelli Farm (1 mile S.E. of Llansantffraid), and again in the dingle south-east of Trewylan House, to which position they are thrown southward by a transverse fault. The limestones contain many fine corals. These beds have not been recognised elsewhere within the area covered by the map.

Above the coral limestones the Ashgillian Beds are in the main fossiliferous nodular mudstones, but contain arenaceous matter in the form of thin tough blue laminated sandstones.

SILURIAN.

The detailed mapping of the main mass of Silurian rocks of the Llanfyllin area by Mr. King has led to the discovery of both Llandovery and Tarannon rocks between the Ashgillian and the Wenlock.

The exact base of the Llandovery is usually difficult to determine. This is largely due to the fact that the Ashgillian tends to become more sandy in the higher parts while the lower parts of the Llandovery, though mainly mudstones, contain sandy or siliceous beds. Certain beds presumably near the base of the Llandovery contain bands of calcareous matter. The mudstone of these strata is as a rule rather more blue than that of the Ashgillian. Fossils are scarce, but specimens of *Pentamerus* have been found, which leaves no doubt as to the Silurian age of the beds. Moreover, beds with *P. undatus*, etc., have been found at Pen-y-godor near the River Vyrnwy, in a syncline on the southern margin of the one-inch sheet.

In the extreme south of the sheet, on Allt-gôch, a massive fine-grained grit with basal conglomerate rests on the Ashgillian beds. The grit itself is some 15 ft. thick, and is non-fossiliferous; but the basal conglomerate, which runs up to 2 ft. in thickness, contains numerous fossils. Most of these appear to be small corals, although a few brachiopods also have been found. The majority of the pebbles in the conglomerate consist of vein quartz and fine-grained igneous rocks.

In the Glyn-Ceiriog valley the Glyn Grit was assigned to the Ordovician; but although the grit of Allt-gôch appears to come in at about the same horizon, the field-evidence, as far as it

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goes, tends to place this grit in the Silurian. The matter will probably be settled when the fossil-evidence has been thoroughly worked out. The grit can be traced northwards to near Pant, a distance of about a mile, where it suddenly disappears.

A soft but massive sandstone, 6 to 10 ft. thick, crops out near Rhôs-fawr, on the western edge of the one-inch sheet, and again on Craig-fawr, still farther west, where it has yielded traces of fossils. As these are indefinite, the position of this sandstone in the sequence remains undetermined.

From the fossil-evidence the Lower Llandovery alone seems to be present in this area, and it is probable that there is a non-sequence between the Lower Llandovery and the Tarannon. As the junction between the two can nowhere be clearly seen, the line adopted for the purpose of the map is that which separates pale grey shales and mudstones above from bluer mudstones with various forms of pentamerids—especially *P. undatus*—below.

However, at one locality (Pont Radin in Nant Alan) near the 1-mile stone from Llanfyllin, graptolites have been found which proved to belong to the *Monograptus turriculatus* zone, while at other localities brachiopods have been found.

The Wenlock-Ludlow rocks are mainly of the usual Welsh type of banded mudstone. Graptolites have been found at various horizons, but are abundant in the lower beds alone. These indicate the *Cyrtograptus murchisoni* zone.

The Denbighshire Grits are strongly developed to the west of the one-inch sheet, where three bands can be distinguished. The lowest appears immediately to succeed the *C. murchisoni* zone, while one of the higher grits forms Craig-fâch. On tracing the grits eastwards they rapidly die out, the lowest one alone extending in an attenuated form to Henrhyd-fawr. No sign of the grits is to be seen along the rest of this outcrop, but at the same horizon the beds are usually sandy and sometimes pass into fine-grained banded sandstones.

On the hill above Ty'n-y-celyn (east of Efail-y-cwm in Nant Alan), at about the horizon of the lower grit, a mass of calcareous conglomerate is found in the normal type of Wenlock sediment. The conglomerate consists of irregular lumps of fine muddy limestone, up to several inches in diameter, in a calcareous muddy cement, in which are also found rounded pebbles of hard black mudstone, which weather out on the surface. The conglomerate contains inter-bedded bands of calcareous mudstone, which show contorted bedding. In places graptolites and small brachiopods have been found in the matrix with the dark pebbles.

A similar, though much thinner, bed is seen at Adwy-wynt, to the south-west. Its exact horizon has not been determined, but the pebbles of dark mudstone fill up hollows scoured out of the banded mudstone to a depth of about 3 in. These peculiar beds must have been formed in shallow water that was subject at times to violent current action, which broke up the more or less solidified calcareous mudstone and eroded hollows in the beds that had already been deposited. The pebbles of black mudstone show such perfect rounding and are so unlike any rock

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exposed in the district, that it must be assumed that they were brought from a distance by strong currents near some older land-surface that was then undergoing erosion.

The mudstones below the conglomerate contain here and there a few similar looking dark pebbles scattered with no apparent method through the beds. These pebbles are much more phosphatic than those of the conglomerate and are probably of concretionary origin.

The main mass of the Wenlock-Ludlow series shows no features of particular interest, and the junction between the two stages cannot be traced without laborious fossil-collecting.

The rocks of the Llanfyllin area are thrown into a series of folds with axes ranging approximately east-north-east and west-south-west. This structure is best displayed by the junction of the Caradocian and Ashgillian stages, along which the Caradocian sandstones stand up as hills, while the soft mudstones of the higher stage tend to produce valleys. The anticlines are not symmetrical, however, for their northern limbs display gentle dips, while their southern limbs present vertical or even inverted dips. This indicates overfolding from the north. In similarly folded ground near Bwlch-y-cibau the Ashgillian and even the Lower Llandovery beds are involved.

South of Llansantffraid also, in the ground mapped by Mr. Smith, the Caradocian rocks are similarly folded. Some of the sandstones form sharp arête-like ridges, the two sides representing respectively the dip-slope and the steep scarp. The physiographical features are intimately related to the geological structure, both hills and valleys ranging themselves along synclinal and anticlinal axes. The hills, though of low elevation, possess a striking individuality rarely to be seen in the greater part of the area north of the Tanat valley. The Ashgillian rocks give rise to country of lower relief. The folding is mainly of post-cleavage date.

CARBONIFEROUS.

The 'Permian' rocks shown on the old map (61 N.E.) at Preston-on-the-Weald-Moors, between Wellington and Newport, have been found by Mr. Cantrill to be referable to the Keele Beds of the Upper Coal Measures. They consist of purple and lavender-coloured soft sandstone, yellowish-red sandrock, and salmon-coloured marl. Though their relationships to the surrounding formations are obscured by Glacial drift, it is probable that they are separated from the Bunter of Kinnersley on the north by a fault. Southward they appear to extend under the Drift towards Trench and Hadley, while south-westward they have been proved in a recent boring at Wellington.

TRIAS.

In the area south-west of Llanymynech, evidence has been obtained by Mr. Smith of the former extension or overstep[1] of the Trias across the Carboniferous rocks on to the underlying Ordovician. The evidence takes the form of a purple stain in

[1] 'Summary of Progress for 1915' (1916), p. 8.

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the Ordovician rocks of the hill-margin overlooking the plain of the Vyrnwy and Severn. This stained area, which forms a belt about half a mile wide, extends from New Bridge Vrynwy (about 1 mile S.W. of Llanymynech) for nearly two miles southward. A little hæmatite also occurs here and there in the joints and divisional-planes, and has encouraged prospecting for ore. In this tract the boulder-clay also is occasionally red in tint. Extensions of the stained belt farther southward may be expected.

Near Wem, in the ground mapped by Mr. Pocock, the Keuper Marl forms a feature, possibly due to faulting, trending north-eastwards from Shooter's Hill through Palms Hill and Brockhurst. To the south-east of this line the marl is practically free from drift and there are many small exposures showing red and grey shaly marls alternating with thin sandstones, the general dip being north-westward at about 2°.

At the Drumble the grey marls contain obscure plant-remains, and show traces of copper, while in many exposures the thin sandstones are ripple-marked and contain occasional salt-pseudomorphs.

To the north-west of this area the Keuper Marl is everywhere obscured by drift.

Farther south, in the district examined by Mr. Cantrill, between Shrewsbury, Wellington and Newport, the Bunter rocks, though almost wholly concealed by Glacial deposits, are exposed in the valleys of the Roden and Tern, and also at several points around Kinnersley. The greater part of the area is occupied by the fine-grained soft bright-red and brown sandstones that form the upper part of the Lower Mottled Sandstone, though outliers of the basement-beds of the Pebble Beds form low elevations at Sugdon, Longdon-upon-Tern, Crudgington, and Kinnersley. These outliers have yielded some dull-red and brown sandstones which, though containing small scattered pebbles of quartz, quartzite and igneous rocks, have proved useful for construction work on the local canals, railways and churches.

GLACIAL DEPOSITS.

The Glacial deposits of the Llanfyllin district examined by Mr. King, consist in the main of grey boulder-clay of local origin. Rocks foreign to the district are extremely rare, although on and north of the watershed between the Tanat and the streams draining into the Cain numerous boulders of the felsites of the Llangynog district can be seen. Striæ on rock-surfaces have been found at various points, and in all cases are directed down the valleys, showing that the lower layers of the ice, or perhaps merely the local ice, moved down the existing hollows. This does not preclude the existence of a main ice-sheet that moved transversely over the local ice from the main Welsh icefield towards the Shropshire plain.

Local patches of sand and gravel are found in the valleys, especially where a tributary enters a main valley. These gravels are probably referable to the latest phase of the glaciation, when small glaciers still occupied the valley-bottoms, the gravel being

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washed into the depression between the two ice-streams, and thrown down at the end of the spur dividing them. Pen-y-bryn Terrace at Llanfyllin is built on one of these gravel-spits.

The ground between the Bryngwyn Hills and the alluvium of the River Cain is covered with drumlin-like mounds of boulder-clay, elongated in the direction of the main valley. Near Llanfechain these drumlins apparently block up the old valley of the Brogan Brook which now, after flowing across a wide alluvial plain, cuts across the drumlins at right-angles in a small shallow gorge to join the Cain below Llanfechain. It is probable that the wide alluvial flat marks the site of what was once a small lake.

The Glacial deposits in Mr. Smith's district south of Llansantffraid are similarly of local or western origin. The chief large boulders are of Ordovician sandstone and limestone, and Wenlock grit. The largest specimen found, measuring 6 ft. by 3 ft. by 2 ft. 6 in., consists of fossiliferous sandstone. In an area of about $1\frac{1}{2}$ square miles south and east of the Vyrnwy, and due south of Llansantffraid, the boulder-clay forms a series of twelve or more shapely drumlins rising from 80 to 100 ft. in height. Their longer axes are arranged either west-and-east, or slightly north-of-east and south-of-west.

Some patches of sand and gravel rise as rounded mounds through the Late-Glacial gravels near the main road about a mile south-east of Llansantffraid, and on the higher ground, 400 ft. above sea-level, a prominent tumulus — Hen Domen—has been erected upon a patch of gravel overlying the boulder-clay.

To the south-east of Ellesmere, Mr. Pocock reports that the drift-covered area of sand, gravel and boulder-clay displays a hummocky topography, with meres or peat-mosses in the hollows, as mentioned in the *Summary* for 1914, p. 15.

The sand and gravel forms a distinct belt trending south-eastward from Ellesmere through Cockshutt to Burlton, and is of considerable thickness, a well at Colemere Woods failing to bottom the sand and gravel at a depth of 75 ft.

The hummocky topography becomes less pronounced to the south of Cockshutt, where the belt of sand and gravel flattens out and reaches a lower level as it extends eastward towards Wem.

To the west of this belt of sand the high ground of Kenwick Park, Stanwardine and Petton is formed of boulder-clay, 120 ft. thick at Petton Farm, on which rest patches of coarse gravel and clayey sand, sometimes forming esker-like ridges with a south-easterly trend, as at Whinnett Hill.

The gravel at Kenwick Park, Stanwardine and Petton is coarse and for the most part unbedded. It contains striated blocks of Carboniferous limestone, fragments and pebbles of coal, and much slaty rubble of Welsh origin, including fossiliferous Lower Llandovery and Bala rocks, together with granite boulders and pebbles probably derived from the Lake District. Fragments of shells of marine species now living were noted in the gravel at Stanwardine, and also in the stiff boulder-clay near Weston Common, while at Petton, in the lower part of the pit near the church, fairly complete specimens have been found. A 3-foot

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boulder near Cockshutt has been provisionally identified as from the outer basic portion of the Carrock Fell gabbro.

Boulder-clay occupies most of the ground between English Frankton and Edstaston, north of Wem, with the exception of a belt of gravel following the course of the River Roden. The town of Wem is situated on a considerable spread of this sand and gravel.

Boulder-clay again occupies the ground between this belt and the outcrop of the Keuper at Shooter's Hill, Palms Hill and Brockhurst.

North-west of Wellington and thence towards Newport, Mr. Cantrill finds that boulder-clay overspreads much of the low country lying east of the River Tern, and extends under the Weald Moors around Kinnersley, past Preston, towards Trench. Much of it is red and loamy, and contains fragments of skerry sandstone from the Keuper Marl outcrop to the north, though the numerous pebbles (some of them striated) of Lower Palæozoic rocks, and of Lake District granites, show that some of the constituents are far-travelled. What are apparently the lower parts of this deposit consist of chocolate-coloured stoneless laminated silt, which seems to have been deposited in quiet water, possibly in a Glacial lake. This silt is dug for bricks at two pits near Longdon-upon-Tern.

Succeeding the boulder-clay an irregular sheet of sandy gravel, sand, and loam extends north-eastward through Admaston to Eyton on the Weald Moors, and thence south-eastward towards Trench. The sand is mainly of Triassic derivation and contains pebbles of Bunter and Keuper sandstone, as well as Welsh sandstones, Lake District rocks and occasional flints and shell-fragments. At Burcot, Orleton, Bratton, and Leegomery, the presence of angular pieces derived from the rocks of the Wrekin shows that some of the constituents were carried out on to the lower ground by ice or by water flowing northward.

Above this sheet of gravel and sand a second bed of boulder-clay sets in and forms the picturesque mounds ground of Dothill and Apley Parks near Wellington. Boulders, ranging up to 4 ft. in diameter, of granite and felsite are common throughout the district.

LATE GLACIAL, POST-GLACIAL, AND RECENT.

The Late-Glacial Flood-gravels of the Vyrnwy, described in previous Summaries of Progress[1], were found by Mr. Smith to form broad spreads upon both banks of the river south of Llansantffraid, breaking away in bluffs rising in places 30 or 40 ft. above the stream. To the south-east of a constriction in the valley of the Cain the gravels become mounds and contain numerous kettle-holes occasionally floored by peat, the largest being nearly 30 ft. in depth.

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[1] For 1914, p. 17; for 1915, pp. 11–12.

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Small tongues of a Late-Glacial Clay known to underlie the gravel-fan that spreads out on the Shropshire Plain penetrate westward into the hill-country. An irregular tract of this clay, similarly related to the gravels, was mapped also in the drumlin-country south of Llansantffraid, on the east bank of the Vyrnwy. Another flat spread of what must be Late-Glacial as distinct from recent alluvium, occurs west of Deythur. These deposits are of fairly homogeneous, unstratified, and usually yellow, clay with few stones, and appear to owe their origin to mud, derived from the boulder-clay, that slid down the slopes to the lower ground almost immediately after the disappearance of the ice.

Low terraces, covered by brown loam with few stones, have been cut in these Late-Glacial beds at a later period, when the volume of the streams had diminished. The recent alluvium is a brown loam with occasional seams of rather coarser material. In the wider parts of the flood-plain it overlies the gravels that appear to form the river-bed.

Along the valley of the Tern Mr. Cantrill finds that Late-Glacial gravels form terraces between Crudgington and Walcot. They consist of materials derived from the earlier drifts, with an increased proportion of flint-pebbles.

The Weald Moors, which occupy a large low-lying area around Kinnersley (between Wellington and Newport), are covered with a thick deposit of peat and peaty alluvium, in which tree-trunks and roots are occasionally discovered. Popular opinion regards the moors as the site of a lake, but no proof of this theory has been obtained. The sluggish drainage of the district probably gave rise to swamps and later to dense woodlands, which further impeded the waters and ultimately led to a thick growth of peat. That the peat was thicker and more extensive before the Marquis of Stafford's drainage scheme was carried out in 1820, is shown by the stilted condition of the trees still growing on and around the peat-covered ground.

(2) WARWICKSHIRE AND STAFFORDSHIRE DISTRICT.

W. Gibson, D.Sc., District Geologist.

E. E. L. Dixon, B.Sc., A.R.C.S.

R. L. Sherlock, D.Sc., A.R.C.S.

T. H. Whitehead, B.Sc., A.R.C.S.

The surveying of the South Staffordshire Coalfield (sheets 167 and 168) and of the region lying to the west (sheets 139 and 153) was continued.

SILURIAN.

The small inlier of Silurian rocks exposed in the crest of the Netherton Anticline at Saltwells, between Brierley Hill and Netherton, has been mapped by Mr. Whitehead. The succession determined by Messrs. King and Lewis[1] in 1912 corresponds

[1] *Geol. Mag.* for 1912, pp. 437–43, 484–91.

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closely with that established by Miss Elles and Miss Slater[1] at Ludlow, and consists of:—

4. Red Passage Beds, red and purple marls and sandstones.
3. Temeside shales, with bone-beds.
2. Downton Castle Sandstones.
1. Upper Ludlow Shales, with bone-bed at top.

For the purposes of the map, Nos. 3 and 4 have been grouped together. In their paper of 1912, Messrs. King and Lewis described the Red Beds (4) as Old Red Sandstone, largely on the grounds that the 'lingula' fauna was not found by them above the Temeside Shales. Lingula has since been found in the Red Beds, and in a later paper[2] Messrs. King and Lewis give reasons for regarding them as of Downtonian (Ledbury Passage Beds) age, rather than Old Red Sandstone.

The brine well at Saltwells seems to have been sunk into these red beds, but it appears that they here have a covering of Coal Measures, as beds containing traces of plant-remains, and having the appearance of Coal Measures, are exposed in the banks of the Blackbrook, immediately to the north. The outcrop of the red beds seems to be truncated by a fault some two hundred yards north of the Saltwell.

COAL MEASURES.

The mapping of the Upper Coal Measures and Middle (Productive) Coal Measures south of the Bentley Faults has been continued by Mr. Whitehead. The evidence from shaft-sections, and such observations as can be made at the surface, show that the passage from the grey Productive Measures to the red and purple Old Hill (Etruria) Marls is gradual. Red marls and 'gritty' rocks are occasionally recorded at several levels in the Productive Measures; and a grit of distinctly 'Espley' type occurs about 15 ft. above the Brooch Coal in Messrs. Doulton's smaller clay-hole at Saltwells.

Whenever the Upper Sulphur Coal is shown in a section, mention is almost invariably made of 'red ground' and 'mingled ground,' together with 'rock' and 'pebbly rock,' above it. It seems convenient therefore to regard this coal, which when present is always about 300 ft. above the floor of the Thick Coal, as marking the top of the 'Middle Coal Measures,' or grey productive measures. This arrangement, which was that adopted by J. B. Jukes[3], has the advantage of including in the Productive Series all the coal seams that have ever been worked. When the Upper Sulphur Coal is not present, it is usually the case that 'red ground,' red 'marl,' etc., begin to appear in the records of shaft sections at about 300 ft. above the Thick Coal. At Birchtree Coppice, near Quarry Bank, and at Mushroom Green, there is a marked development of grits and conglomerates, at a level which seems to correspond sufficiently nearly to that at which the

[1] *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 195.
[2] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 90.
[3] 'The South Staffordshire Coalfield,' *Mem. Geol. Surv.*, 2nd ed., 1859, pp. 28–31.

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Upper Sulphur Coal commonly occurs, to justify the use of these beds as a base for the Etruria Marls. Similar conglomeratic and gritty beds are strikingly developed about Dixon's Green and Tansley Hill, but here they seem to persist to a higher level. In the absence of such beds at or near the plane of division, it is only possible to indicate vaguely the boundary between the area of the Productive Measures outcrop and that of the Etruria Marls, by the aid of information as to depth of the Thick Coal derived from numerous shaft-sections.

The thickness of the Old Hill Marls is about 300 ft. near Old Hill, and probably less than this near Blackheath and Cakemore. Towards the north they increase to about 350-400 ft. east of Dudley Port Station.

The Halesowen Beds come into the area surveyed near Cakemore and Blackheath. In the Cakemore marl-pit there occur yellowish grits and conglomerates which rest on purple marls, and which have been identified by Mr. Kay[1] as belonging to his 'Witley Group' of the Halesowen Sandstone series. Having regard, however, to the level of the Thick Coal under the marl-pit, where it stands at 149 ft. above sea-level, giving a depth of less than 450 ft., it seems more reasonable to regard these arenaceous beds as 'Espley' rocks in the Etruria Marls. Very similar beds occur in the Etruria Marls near Tividale and Rounds Green. On the higher ground of the golf course, south of Cakemore marl-pit, and at Round Hill Farm, greenish sandstones and conglomerates of the Halesowen series appear, and are thrown by the eastern boundary-fault against the red beds of the Hamstead group about midway between Round Hill Farm and Brand Hall. Similar indications of Halesowen Sandstone appear on the higher portion of the ground enclosed by the munition factory north of Hurst Green, and also at Rowley Regis Station. The brick-pit, about 250 yards south-west of the station, exposes greenish-grey sandstones overlain by grey clays with signs of a thin coal and yielding many blocks of spirorbis limestone. These clays belong to Mr. Kay's Halesowen Coal and Clays group[2], and are thus well above the base of the Halesowen Beds as a whole. It appears probable, therefore, that the Halesowen Beds outcrop may extend sufficiently far north to include the site of the coal-shafts about 300 yards north of the brick-pit and near Rowley Regis Station, though the depth to the Thick Coal in these shafts is stated to be only 606 ft. South of Old Hill, and in most localities farther to the north, Etruria Marls appear at the surface where the Thick Coal is at a depth equal to, or even considerably greater than this. It is, however, not to be expected that a plane of division, based on purely lithological characters, should maintain a constant position with reference to a datum, such as the Thick Coal floor, when traced over even comparatively short distances. This is especially true of a plane intended to separate two such variable groups as the Etruria

[1] *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 441.
[2] *Op. cit.*, p. 443.

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Marls and the Halesowen Beds, the passage from one to the other of which, is, moreover, so gradual.

Hamstead Beds.—On the upcast side of the Eastern Boundary Fault, south of Oldbury, brown-red, soft sandstones appear, with lenticles of coarse limestone-conglomerate, the latter giving rise to conspicuous features south of Langley Green and near Brand Hall. Pebbles of chert and of limestone, chiefly Carboniferous, but including some Silurian,[1] are abundant in these conglomerates. The proportion of limestone-pebbles relative to those of other kinds, appear to increase as the exposures are followed from south to north, and may be as high as 50 per cent. In a gravel-pit near Bristnall Fields, east of the Bristnallhall-road, and also in the lane called George-road, leading to Warley Woods, there occur breccia-beds, with small subangular pebbles, interbedded with soft sandstones and marls. Pending further evidence from the ground to the south-west as to the persistence of these breccia-bands, no attempt has been made to draw precise boundaries for them.

Igneous Rocks.—The dolerite and basalt of the Rowley Hills may be seen intruded into Etruria Marls near St. Giles's Church, Rowley Regis. There it is in the form of small dykes or sills in the marls, some of the sill-like intrusions being only an inch or two in thickness. No perceptible alteration is produced in the marls.

South of Netherton Church, the small exposure of basalt in the canal-section seems to afford evidence that the intrusion was later than the formation of the fault there exposed to view. The basalt has the appearance of running up the scarp face of massive Downton Castle Sandstone, where that rock is truncated by the fault, and does not cross the fault-plane. About 30 yards to the south, however, where the sandstones against the fault are flaggy, the igneous rock crosses the fault and intrudes itself as sills between the flags. Where the basalt is intruded into the red Downtonian sediments in the canal-bank, some metamorphosis of the sediments has taken place.

Faults.—Mining-plans make it clear that the Russell's Hall Fault, along the western flank of the Rowley Hills, is a complex system of fractures occupying a strip of ground from one to two hundred yards broad. It is in fact part of a belt of much faulted ground nearly half a mile broad. South of Dixon's Green the Russell's Hall Fault is stated to have no hade in the Thick Coal, and to vary in the amount and direction of its hade as it is followed upwards. The downthrow here is believed to be 150 ft. to the south-west, and this throw increases towards the south, but the amount, so far as can be ascertained, has not been actually proved, as the fault usually forms the boundary of properties, and is in consequence never crossed by any workings.

The Eastern Boundary Fault is well marked between Cakemore and Warley by the contrast between the grey Halesowen

[1] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 115.

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Beds on the downthrow side and the red Hamstead Beds on the upthrow side. The throw here must be about 1,100 to 1,200 ft. Smaller faults to the west throw the Halesowen Sandstone down to the east. There is, in fact, a belt of faulted ground extending over a considerable distance east of Cakemore and Oldbury. The trial-boring made some years ago between Langley Green and Londonderry was evidently situated in this disturbed belt, as was shown by the faulted condition of many of the beds passed through.

In the district, surveyed by Mr. Dixon, around Bushbury and Hilton Park, on the western margin of the South Staffordshire Coalfield, north of the Bentley faults, the structure is similar to that at Shareshill and Saredon, as described in the Summary of Progress for 1915, pp. 12–13. Barren red Upper Coal Measures, referable to the Keele and Hamstead Beds, occupy much of the surface, and the Bunter Pebble Beds are confined to isolated outliers on the highest ground. As elsewhere in the Midlands, the Hamstead Beds include water-bearing sandstones and breccias or conglomerates, in which subangular yellow and red cherts derived from the Carboniferous Limestone are abundant. Pebbles of Limestone, though more local, also occur. Similar rocks occur around Lilleshall, and are doubtless referable to the Hamstead Group.

TRIAS.

The examination of the Triassic Rocks which separate the South Staffordshire Coalfield from that of Coalbrookdale, has been continued. Great variability in the development of the three sub-divisions of the Bunter is met with. In the Bushbury area, for instance, Mr. Dixon finds that the Bunter commences with the Pebble Beds, the Lower Mottled Sandstone being overlapped or not developed. Farther north, beyond Penkridge, the Upper Mottled Sandstone is also wanting; but in the Newport district to the west, and generally along the margins of the Coalbrookdale Coalfield, all three sub-divisions are represented.

In the Bushbury district the Bunter occurs in the form of outliers resting on high ground composed of Upper Coal Measures. Farther west Bunter Sandstone, succeeded by Keuper Sandstone and Keuper Marls, forms a broad tract running parellel with the Upper Coal Measures. The junction of this main outcrop with the Upper Coal Measures is not seen, but as generally thought, it is probably a fault, though not necessarily one of large magnitude.

In the Newport district, the Lower Mottled Sandstone presents in several places, and through a thickness of several feet, a remarkable development of 'millet seed' sand, the grains being large, uniform in size and nearly spherical.

East of Brewood two deep borings for water are in progress, and the cores have been examined by Dr. Sherlock. The one at Somerford, after passing through Keuper Marl and Keuper

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Sandstone, has proved 200 ft. of non-pebbly Bunter Sandstone. The other, at Slade Heath, shows that the Drift rests on Bunter Sandstone containing a few pebbles.

South of Smethwick, in the area surveyed by Mr. Whitehead, around Warley Abbey, the Bunter consists of lenticles of sand-rock and of semi-consolidated pebble-beds. What appears to be an outlier of these beds survives on the high ground at Hilltop, near Bristnall Fields. The Lower Keuper Sandstone in the Newport area is a typical, coarse, conglomeratic, brown rock, easily distinguishable from the Upper Mottled Sandstone. Southwards, towards Boscobel, Dr. Sherlock finds the Keuper Marls passing down into soft, brick-red sandstones, resembling Lower Mottled Sandstone, and farther east, near Corven and Featherstone, Bunter and Keuper Sandstones are difficult to distinguish.

GLACIAL.

In the district round Newport (Salop) mapped by Mr. Dixon, the glacial deposits fall into three groups:—(1) unbedded clayey-drifts; (2) high-level gravels and sands; (3) low-level gravels, sands and laminated loams and clays.

The unbedded drifts, which are of the nature of 'till,' bear no particular relation to the topography. The high-level drifts cover some of the highest parts of the Keuper Marl outcrop east of the Bunter ridge, fringing the Coalbrookdale Coalfield. The third set appears to have been laid down partly in a lake covering the site of Newport, and the ground to the west, and partly by waters escaping from this lake into valleys draining to the east and south as surmised by F. W. Harmer.[1]

A stiff chocolate-clay, with a local development of loose red sands at its base, occupies the low ground in the Shifnal area. Dr. Gibson notes that this clay is of sufficient thickness to prevent much of the rainfall from percolating into the underlying Lower Mottled Sandstone, and that a geological map, on which superficial deposits are omitted, gives no clue to the character of the soil and subsoil. In the Keuper Marl area, round Boscobel, surveyed by Dr. Sherlock, glacial sands and gravels attain a considerable development, and give rise to a light soil of less agricultural value than that formed out of Keuper Marl.

The well-marked features determined by the 'solid' geology of the Cakemore and Warley area are observed by Mr. Whitehead to die away northwards under a blanket of unbedded pebbly drift. Similar material, but with a larger admixture of clay, lies on the watershed at Blackheath, at a height of about 840 ft. West of Rowley Regis, drift is absent, except for a few signs of it, in the form of clay with pebbles, near Mousesweet, near Old Hill, and scattered Bunter pebbles at Quarry Bank. A small patch of pebbly drift lies at a height of 800 ft., north of Turner's Hill, on the Rowley ridge itself.

[1] *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 478.

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(3) LEAD, ZINC AND COPPER MINES.

The Northumbrian area was examined by Dr. Stanley Smith, the rest of the Pennine Chain by Mr. Carruthers. Throughout this region, the great majority of the productive veins are in Carboniferous Limestone and Yoredale strata, though a few traverse the Millstone Grit also. They are characterised by a comparatively rapid impoverishment in depth, generally because the fissures "pinch out," but occasionally on account of replacement by other minerals. It is rare to find a vein carrying commercial quantities of ore below 100 fms., and it is not surprising to find that after centuries of working, most of the mineral fields, taken as a whole, show signs of exhaustion. There are notable exceptions, however. The famous "flats" of the Boltsburn Mine, in Weardale, discovered 27 years ago, are still in full work. They appear to be metasomatic replacements of the limestone, parallel to, but rarely in contact with, a thin vein, which has presumably acted as a "feeder."

The Alston Moor country continues to be an important producer, especially for zinc-blende, of which considerable reserves exist. Metasomatic 'flats' are found here also.

Most of the Derbyshire mines, once so numerous and so active, closed down many years ago. Millclose Mine, marked by immensely rich chamber-deposits on either side of the lode, is still in active work. The headings are now far under the Yoredale Shales, nearly two miles from the limestone-outcrop. Most of the innumerable veins scattered over the limestone massif in this country are probably exhausted, but if some efficient means could be devised to cope with the heavy underground water, some of the great "rakes," now drowned out, might again produce galena in quantity.

Interesting evidence as to the date of the Derbyshire ore-deposits is provided by the small lead- and copper-working at the Snelston Mine, near Ashbourne. The ores are found in a fault bringing down Keuper Marl against Carboniferous Limestone, so that, here at any rate, the mineralisation seems to be definitely post-Triassic.

The occurrences of galena and blende in the Carboniferous Limestone and Chert series of Flintshire and Denbighshire were examined by Mr. Bernard Smith, with a view to bringing up to date the detailed account given in the Memoirs on the Geology of Flint, Mold and Ruthin (1890) and the Geology of the Coasts adjoining Rhyl, Abergele and Colwyn (1885).

The abandoned mines near Minera, in ground recently surveyed, were also studied.

The chief mines still in work are in the Halkyn District, but others are ready to reopen in both this and the Holywell districts if deep drainage can be secured or labour-conditions permit. In depth the lodes appear to carry a higher proportion of blende than galena. The future development of this region depends upon a successful unwatering of the ground. The old

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Halkyn Tunnel, driven southward as far as the Llyn-y-pandy Lode, about four miles south of Halkyn, at approximately 200 ft. above sea-level, no longer serves the purpose, for most of the mines unwatered have been worked down to, or below, its level. Further work in these mines entails costly pumping.

It is now proposed to carry the Milwr or sea-level tunnel, which has already proved several of the lodes in depth in the Holywell area, southward into the Halkyn district, and extend it eventually into the Llanarmon field. It is hoped that in that area numerous veins, that have yielded richly in the past, may be found to be prolific in the eastern parts of their courses. The southern extremity of this tunnel is now at the northern boundary of the Halkyn Mines District Drainage Area, and about 200 ft. below the old tunnel.

During the closing stages of the war a pumping-scheme, financed by the Government, was commenced at North Hendre Mine, to unwater several bearing lodes below the Halkyn Tunnel level, but this scheme is in abeyance.

Little is being done at the present time in the Minera district, chiefly owing to the fact that the great Minera veins contain blende, but little galena, in depth, and pumping-charges are prohibitive.

In the Minsterley district of Shropshire, again, the future of the mines depends upon deep drainage. Here the ores of lead and zinc occur chiefly in the Mytton Beds overlying the Stiper Stones quartzite and beneath the Hope Shales—all of Arenig age.

The Leigh Adit Level (399 ft. O.D.) has been completed as far as the Milne Shaft in the Hope Valley, and is now being driven southward to cut a large series of veins formerly worked in the old "Gravels" and "Grit" Mines. Should these prove to be rich beneath the old workings a promising future is assured for the Shropshire Mines. For the Bog Mine pumping has been proposed. At the present date the chief product of the district is barytes, got from shallow levels above water-line.

Mr. Smith also examined occurrences of lead- and zinc-ores in the Ordovician and Silurian rocks, near St. Asaph, in Flintshire, Llansannan, in Denbighshire, and Llanrhaiadr and Llangynog in Montgomeryshire. The Pennant Mine, St. Asaph, is alone in operation.

Some scattered occurrences of copper-ore were also investigated in Denbighshire and Shropshire.

The mines for lead, zinc and copper in Cornwall, Devon, Somerset, Shropshire, Cheshire, Carnarvonshire, Merioneth and Anglesey, were visited by Mr. Dewey.

In Cornwall and Devon, the lead- and zinc-ores occur principally in lodes which course north and south and frequently underlie east. They traverse slates and sandstones of pre-Devonian, Devonian and Carboniferous age. Their gangue

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minerals consist of calcite, fluorspar, barytes, quartz and chalybite. Galena and blende often form an intimate complex; but, blende is the principal constituent in some lodes, as at Wheal Sally and Wheal Alfred. In North Cornwall, where the lodes appear in and near flows of lava, galena is the dominant mineral; it is rich in silver and is frequently accompanied by the ores of antimony.

Lodes bearing galena and blende were formerly worked by opencast pits sunk in the Carboniferous Limestone of the Mendips, and calamine and blende were also mined in the Triassic Basal Conglomerate on the flanks of those hills. No mines, however, are now in work and the dumps have been thoroughly worked over.

Ores of copper, lead and cobalt occur, mainly as carbonates, in the Keuper Sandstone and conglomerates of Alderley Edge, Cheshire. In the underground workings the distribution of the ores is seen to be patchy. Percolating waters have impregnated the sandstone with ores in the neighbourhood of faults and the drainage-waters in the mine are coloured a brilliant green by carbonate of copper. Rich impregnations of galena up to 3 ft. in length can be seen in several of the levels. The mineral envelops the grains of sand and even the pebbles of the conglomeratic beds. The normal 'ore' consists of fine-grained sandstone with a cement of green and blue carbonates of copper.

At Grinshill and some other workings near Shrewsbury, copper-ores have been mined in the New Red rocks and appear to be identical in mode of occurrence and of formation to those of Alderley Edge.

Near Llanrwst, in Eastern Carnarvonshire, there is a large group of mines working lead- and zinc-ores, in most cases by day-levels above adit. The country rock is of Lower Palæozoic age and is fissured by two sets of lodes which course either north and south or east and west. These lodes, in many cases, are mineralised 'shatter-belts' and consist of brecciated country-rock cemented together with calcite, galena and blende. There are indications of a succession of minerals in the lodes from east to west. The Aberllyn Lode consists mainly of brown blende in the form of shear lenticles, galena being rare. A little farther to the west galena forms the principal constituent with a calcite gangue, as at Parc Mines; quartz as a gangue then appears at Old Llanrwst Mine, where it forms a remarkable spongy mass of bipyramidal crystals embedding idiomorphic crystals of galena. Almost due north from these mines pyrites becomes an important accessory. At Cae Coch it is the principal ore and has been wrought.

In Anglesey metallic copper is still being obtained regularly from the drainage-waters of the Parys Mountain Mines by precipitation on scrap-iron; but further mining is not at present anticipated. Some auriferous copper-ore is being mined at Rhos-mynach, Anglesey, and from the old gold-mines of Figre

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and Clogau, near Dolgelley. Zinc- and lead-ores are mined at Moelwyn and Bwlch-y-plwm Mines.

In the Lake District (examined by Mr. Eastwood), ores of lead, zinc and copper are found in Lower Palæozoic strata. The veins around Keswick are in the Skiddaw Slates; those of the Greenside and Coniston fields are in the Borrowdale Ashes, while in the Caldbeck Fells, both rock-groups occur, associated with a complex of igneous rocks.

Most of the veins are filled with broken 'country-rock,' cemented with mineral matter. The leading constituents of the gangue are quartz and barytes, the latter, when in bulk, being restricted to the higher parts of certain veins. Some of the so-called 'lead' lodes contain more blende than galena. Although there are numerous exceptions, 'copper' veins usually trend east and west; hading south, while 'lead' and 'zinc' veins range within 45° either way of north and south, and dip to the east. 'Copper' lodes are sometimes shifted by those carrying 'lead,' while the latter are frequently displaced by barren east and west cross-courses.

The chief ores now raised are those of lead and zinc. Over the whole area, as compared with the Pennines, the galena is notably rich in silver. The amount varies greatly, and seems to have some relation to the presence of barytes. In veins where barytes is abundant, as at Force Crag, the silver content is high —over 30 ozs.—while in lodes carrying little or no barytes (Thornthwaite Threlkeld) it is low—about 10 ozs. of silver per ton of pig lead.

The only zinc-ore of commercial importance is blende. When this occurs with barytes the difficulty of separation, almost insuperable in the old days, has now been got over by oil flotation. The Elmore plant at Force Crag gives a clean blende concentrate, while the crushed barytes is re-dressed and sold as 'barytes sand.'

The lead-zinc ore mines now active are Greenside, Thornthwaite, Threlkeld and Force Crag. Brundholme in Glenderaterra Valley has been re-opened, while at Goldscope in Newlands Vale an attempt is being made to locate the intersections of the copper-lode and 'Sealby's lead vein' in the hope of proving an ore-body similar to that of the great lead-bunch of the Goldscope lead-vein.

No copper-ores are being raised at present, though Coniston, Goldscope and Caldbeck Fells were large producers many years ago. The extensive dumps at Coniston, averaging 1½ ozs. of metallic copper per ton, have recently produced a few tons of sheet-copper by an electrolytic process, but work is now suspended during reconstruction. The chief ore is chalcopyrite, which is associated with iron and arsenical pyrites. Secondary malachite and chrysocolla also occur, but not abundantly.

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(4) Borings for oil in Derbyshire and Staffordshire.

From June to October Mr. Bromehead was stationed at Chesterfield and kept the seven Derbyshire borings under continuous observation, examining all samples of the rocks pierced as they were obtained. In Staffordshire, similar work was done by Mr. Eastwood, who was surveying in that district. By October progress in Derbyshire had become so slow, owing to engineering difficulties, that thenceforward occasional visits only were necessary to obtain all the geological information available.

An account of the progress made up to September, 1919, has been inserted in the second edition of the Special Report on the Resources of Mineral Oil, Kimmeridge Oil Shale, etc., now in the press. The depths and the formation reached by December 31st. are given in the following table:—

Well.	Depth. Sept., 1919.	Depth. Dec., 1919.	Formation reached.
	ft.	ft.	
Ridgeway...	2,815 ...	2,996 ...	Carboniferous Limestone.
Renishaw ...	3,650 ...	3,645 ...	Limestone Shales.
Brimington	2,650 ...	2,660 ...	Limestone Shales.
Heath ...	2,897 ...	2,955 ...	Limestone Shale or Millstone Grit.
Hardstoft ...	3,112 ...	3,112 ...	Carboniferous Limestone.
Ironville 2...	3,570 ...	3,570 ...	Carboniferous Limestone.
Ironville 1...	2,430 ...	2,580 ...	Carboniferous Limestone.
Werrington	1,282 (Oct.)	1,920 ...	Pendleside Series.
Apedale ...	1,350 „	1,350 ...	Lower Coal Measures.

The amount of oil obtained at Hardstoft to the end of the year was 1,900 barrels as compared with 849 barrels to October 1st. The large increase is due to a bailing-test having been made early in December. When the level of the oil was kept at a depth of 1,600 ft., the yield was 20 barrels a day, while with a level of 3,000 ft. as much as 35 barrels was obtained.

At Ridgeway a heavy flow of salt water was met with at 2,898 ft. This water apparently came from the Limestone; it had a temperature of about 110° F. and contained some hydrogen sulphide.

The seepages and other evidence for the presence of petroleum in the Lower Carboniferous rocks of Derbyshire, on which, in part, this exploration was based, lead Mr. Bromehead to suggest that it is the lower part of the Limestone Shales, rather than the Limestone that contains the oil. In many parts of the world, California, Mexico and Galicia for example, where petroleum is indigenous to shales, it is found that commercial supplies are only obtained when a suitable reservoir-rock is brought into oblique contact with the shales. When a porous rock cuts across the bedding of the shale, owing either to unconformity or to faulting, the oil passes by capillarity along the laminæ of the shale, which is impervious in a direction at right angles to the bedding, and accumulates in the porous rock. It

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would appear that the conditions in Derbyshire are of this nature. The section at Kelham indicates that the Millstone Grit is faulted against the Limestone Shales.

At Hardstoft an important fault, proved in adjacent collieries, may be estimated to intersect the boring at a depth of rather more than 3,000 ft. This fault may possibly be connected with the disturbance indicated at Kelham. Its effect at Hardstoft would be to bring limestone into oblique contact with shales, and as a fact between the depths of 3,070 ft., where oil was struck, and 3,112 ft. the samples consist of a mixture of shale and limestone. Again, the character of the oil obtained, its light gravity and colour and low sulphur-content, indicate a shale rather than a limestone as the parent rock.

This theory of the origin of the oil and of the conditions requisite for its accumulation account for the success at Kelham and Hardstoft, provides a reason for the failure at Ridgeway and the two Ironville borings, where the structure was regarded on the anticlinal theory as exceptionally favourable, and does not afford much expectation of success at the remaining wells.

(B)—SCOTLAND.

The surveying of the districts which were in hand in 1914 was in part resumed in 1919. The work had been proceeding in two districts in the Highlands, viz.—

(1) West Highland District under the late Dr. C. T. Clough.

(2) North and Central Highland District under Mr. L. W. Hinxman (now retired).

at the same time revision of the coalfields was proceeding in:—

(3) Ayrshire (Kilmarnock District) under Dr. Clough.

(4) Renfrewshire and South Lanarkshire District, under Mr. Hinxman.

No field-work was done in the West Highland District during the year.

(1) North and Central Highland District.

The igneous rocks of Lower Banffshire and North-west Aberdeenshire (Sheets 86 and 96) have been divided by Mr. Read into an Older or largely pre-foliation series and a Younger or post-foliation series.[1] The Younger Series occurs in two great masses—the Huntly Mass, which was described in last year's Summary of Progress[2]; and the Insch Mass.

[1] 'Summary of Progress' for 1918, *Mem. Geol. Survey*, 1919, p. 24, *Geol. Mag.*, 1919, p. 364.

[2] *Loc. cit.*, p. 28.

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The Insch Mass.

The northern part, which alone comes within Sheet 86, extends eastwards from the Old Red Sandstone of the Bogie Valley for 16 miles almost to Old Meldrum; and northwards for about 2 miles into Sheet 86. The direction of elongation of this and of the Huntly Mass, coincides mostly with the strike of the neighbouring metamorphic rocks.

The rock-types found in the northern part of the Insch Mass are olivine-norite, hypersthene-gabbro, quartz-diorite, syenite and granite. Other types—troctolite, probably peridotite, etc.—occur outside Sheet 86; and until these occurrences have been examined, consideration of the relative ages of the different rock-types must be held over. The order given above is likely to be that of relative age, beginning with the oldest.

Olivine-norite.—The main part of the northern portion of the Insch Mass is formed by two rocks, an olivine-norite and a hypersthene-gabbro. These are easily separable in the field and under the microscope, but whether they are two independent intrusions or only phases of one intrusion, is not yet determined. The olivine-norite forms the north-western part of the gabbro of the Insch Mass. In hand-specimen it is a coarse, dark-greyish rock. It weathers to a great depth in spheroidal masses which contain oval nuclei of fresh rock, the final result being a coarse reddish sand and a soil of great fertility. In slice, the rock is seen to consist of labradorite, olivine, hypersthene, augite, biotite, hornblende, magnetite and apatite. The felspar occurs in large fresh crystals. The olivine is abundant in large rounded grains often bordered by pyroxene. The hypersthene forms large prisms or fingered plates with well-marked pleochroism in green to pink tints, and commonly occurs as a border to rounded olivine-masses. The monoclinic pyroxene forms stout prisms, greenish in colour, with well-marked basal striation and is usually much subordinate to the orthorhombic variety. Yellow to deep-brown biotite builds large plates, often associated with iron-oxide masses. Brownish-green hornblende is of secondary origin and borders the pyroxenes. Apatite is abundant in small clear hexagonal prisms. Variations from this main type are formed by differences in the relative amounts of the two varieties of pyroxene. Occasionally the rock approximates to an olivine-labradorite rock, but then it is easily distinguishable from the troctolites of the Huntly Mass.

Hypersthene-gabbro.—This type of gabbro is found in general in the north-eastern part of the Insch Mass. It is finer in grain than the olivine-norite and weathers into rectangular slabs. In slice it is characterised by an equigrained structure and is made up of labradorite in stout crystals, vividly pleochroic hypersthene-prisms, marginally altered to fibrous green hornblende, abundant augite-prisms with a diallage-structure, and rather large irregular clots of magnetite. Variations from the main type are brought about by changes in the relative amounts of the two pyroxenes.

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Quartz-diorite.—This rock covers much ground in the parish of Kennethmont. It is a fine-grained greenish-grey rock composed of plagioclase, quartz, hornblende, biotite and accessories. The felspar varies from oligoclase to andesine and builds well-formed crystals, often zoned. Quartz is interstitial to the felspars and somewhat variable in amount. Hornblende, yellow-green in colour, is associated with the yellow to black biotite in clusters and rude groupings. Kernels of pyroxene have been observed in the hornblende. The accessories are magnetite, sphene and apatite.

Syenite.—A rock meriting the name syenite is found in the Wardhouse district. It is a coarse rock, showing in hand-specimens large pinkish felspars and small patches of hornblende and biotite. It is usually much weathered, yielding a coarse felspathic sandy soil. In slice, the felspars are seen to be microcline and oligoclase; the former occurs in large plates of last crystallisation, the latter forms turbid well shaped crystals. Quartz is rare. The ferro-magnesian constituents consist of biotite in large, ragged, yellow to deep-brown plates, and of a deep-coloured brownish-green hornblende. Magnetite and zircon occur as accessories. Near Wraes, the syenite has altered the olivine-norite into a rock with large plates of black biotite.

Granite.—Intimately associated with the syenite, and probably not separated in time, is a fine-grained pink granite, well seen near Weets in the Wardhouse district. In slice, this rock is composed of plentiful quartz, abundant microcline and a finely striped oligoclase in large plates. Ferro-magnesian minerals are rare and limited to small patches of a dark greenish-brown hornblende. A similar rock occurs in small knobs breaking through the gabbros at Knockenbaird and Jackston.

Dyke Rocks of the Insch Mass.

Lamprophyre.—In the syenite-area about the Shevock Burn thin dykes of a very rotten lamprophyre are found. The pink- and green-speckled rock shows small round pea-like patches of a dirty-white felspar.

Quartz-dolerite.—A forty-foot quartz-dolerite dyke occurs in the olivine-norite at Auchinbradie, north of Insch. It presents well-marked chilled edges against the norite. In slice, it is seen to be composed of quartz, labradorite, augite and iron-oxide in coarse ophitic association. The quartz-dolerite has an east-and-west trend, and on its line, about a mile west of Auchinbradie, there is a small outcrop of a beautifully variolitic basalt. Other quartz-dolerites with a similar trend occur in the slate and knotted schist areas to the north of the Insch Mass at Blackford, Rothienorman, Petty and Minnonie (Fyvie).

Granite.—In the Shevock Burn several small dykes of acid rock are found, characterised by inclusions of numerous small pieces of hornfelsed slate. The acid dykes contain pink garnet and, according to Dr. Mackie of Elgin, orthite.

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Cordierite-Norites of the Insch Mass.

It was shown in last year's 'Summary of Progress'[1] that cordierite-norites, formed by incorporation of sediment in the norite of the Huntly Mass, are widespread. In the Insch Mass, cordierite-norites and associated rocks capable of a similar explanation have been discovered in the Saphook district, west of Old Meldrum. Here the norite of the Insch Mass gives place to a rock which, while preserving proof of its igneous origin, is crowded with ghosts of sedimentary xenoliths in an advanced state of incorporation in the norite-magma. The minerals of this set of contaminated norites are quartz, various plagioclases, cordierite, biotite, garnet, spinel, sillimanite, hypersthene, zircon and magnetite. This mineral assemblage is similar to that already known from the cordierite-norites of the Huntly Mass. The Saphook group of contaminated norites occurs on the margin of the Insch Mass; the contiguous sediments are the gneiss and mica-schists of the Old Meldrum area.

Contact effects of the Insch Mass.

The contact alteration produced by the igneous rocks of the Insch Mass on the slates on its northern border was briefly mentioned in last year's 'Summary.'[2]

The gradual passage from unaltered well-cleaved slate to a massive spotted rock and finally to a true hornfels was there described. Further work has confirmed those observations. The spots of the spotted-rock zone are due to the heaping together of dusty materials in areas of incipient crystallisation of cordierite and andalusite. Nearer the igneous rocks, the spots give place to definite crystals of andalusite and patches of cordierite, accompanied by sillimanite, garnet and the reddish biotite of the cordierite-hornfelses. At the junction with the igneous rocks, granular pyroxene-hornfelses are found, characterised by the occurrence of pyroxene in small rounded granules. Small plates of biotite, scarce brown hornblende-prisms, grains of clear plagioclase and quartz complete the rock. Some of the cordierite-hornfelses are banded with vividly pleochroic grains of hypersthene. Such spotted rocks and hornfelses are demonstrated to be the result of contact action of the Younger Igneous rocks on slate, but at the eastern end of the Insch Mass a series of andalusite and cordierite-bearing rocks of a different type is observed. These andalusite-schists are especially well seen in the Ythan Valley about Fyvie, whence they run southwards into the aureole of the Insch Mass. They have no kind of relation to any of the masses of Younger Igneous rocks exposed at the surface, but, lithologically and structurally, are comparable to the Older Andalusite-Schists already described from other parts of Sheets 86 and 96.[3] Unfortunately, exposures of the Fyvie

[1] 'Summary of Progress for 1918,' *Mem. Geol. Surv.*, 1919, pp. 29, 30.

[2] *Ibid.*, p. 31.

[3] *Ibid.*, pp. 30, 31.

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Older Andalusite-Schists are poor within the aureole of the Insch Mass, but such as do occur point, though somewhat indefinitely, to a superimposed metamorphism.

(2) Revision of Carboniferous areas.

Ayrshire and Renfrewshire.

A considerable area of the 'Clyde Plateau Lavas' of Sir Archibald Geikie's classification[1] has been revised during 1919. Mr. Richey has worked on an anticlinal belt reaching north-east through Beith, separating the Ayrshire from the Renfrewshire Coalfields, and also on exposures connecting Dunlop and Busby. He has found in this region a persistent top group of microporphyritic basalts of Dalmeny type, accompanied by subordinate macroporphyritic flows, as for instance at Busby. Mr. Bailey has taken up the mapping from Lochwinnoch to the Clyde, on the west side of the Renfrew basin, and has followed this top group in strong development until, about three miles north-east of Bridge of Weir, exposures fail. It is in keeping with Mr. Anderson's[2] earlier work in the Cathkin Hills, east of Busby, that the Dalmeny type, so characteristic in Fife and the Lothians of Geikie's "puy" eruptions, should here enter largely into the constitution of the Clyde Plateau.

Beneath this persistent group of Dalmeny basalts the sequence is more variable. In the Beith anticline Mr. Richey has mapped a thick succession of macroporphyritic basalts of Dunsapie and Markle types, with an intercalation of Dalmeny flows exposed at Rowbank Reservoir and again (probably) west of Neilston. Between Lochwinnoch and the Clyde also, Mr. Bailey finds macroporphyritic basalts in this position, but in their downward continuation these basalts are interbedded with conspicuous mugearites.

Finally south-east of the Beith anticline Mr. Richey observes that the Dalmeny group is separated from underlying macroporphyritic basalts by well-characterised local zones as follows—

(*a*) East of Neilston: mugearites with small felspar-phenocrysts.

(*b*) Half way between Neilston and Dunlop: microporphyritic basalts of Jedburgh type replacing (*a*).

(*c*) North of Dunlop: mugearites (distinguishable from (*a*)) and other trachydolerites, along with Jedburgh basalts (the southern continuation of (*b*)). Trachyte-lavas (20059, 20093, 20102, 20192) and keratophyre (20193) also occur, but their field-relations to other groups have not as yet been definitely fixed.

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[1] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 368.

[2] E. M. Anderson in 'The Geology of the Glasgow District,' *Mem. Geol. Surv.*, 1911, pp. 102–104.

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Great petrological interest attaches to the Dunlop district. The Calciferous Sandstone lavas of East Lothian, long ago described by Dr. Hatch,[1] include a varied assemblage of trachytic lavas, but, except for minor occurrences in Bute,[2] similar lavas have not hitherto been recorded from the Clyde Plateau, though intrusions of the type are well known. Another link between Dunlop and East Lothian is the presence of hornblende trachydolerites (20060, 20101) recalling kulaite[3].

With the lavas just described, Mr. Richey has mapped a number of volcanic plugs. Of these, two may be selected for mention—(1) a large twin plug of trachyte, two miles north-east of Beith, and (2) a ring-dyke of gabbro surrounding and chilled against an intrusive complex of macroporphyritic basalt, a quarter of a mile east of Greenside Farm, half way between Beith and Neilston. The rocks of the Greenside complex show interesting pneumatolytic effects with the production of albite and epidote. The ring-dyke itself is of unusually small dimensions. Its interior diameter varies from about 150 to 220 yards, and its annular breadth some 30–60 more. It seems feasible to suppose that vertical movement of the earlier central plug resulted in a surrounding cavity which was filled by uprising gabbro-magma.

In the district mapped by Mr. Richey, the Calciferous Sandstone sediments, immediately above the lavas, consist essentially of volcanic detritus of various degrees of coarseness and usually red in colour. These red sediments are fairly rich in iron oxide, as a rule in small scattered grains, but sometimes in definitely oolitic bands.

The lavas below the detrital zone have been rotted by contemporaneous subaerial weathering, as in the case of the top lavas of the Millstone Grit[4] in the same neighbourhood described in Summaries of Progress (*Mem. Geol. Surv.*) from 1913 onwards. Unfortunately valuable beds of fireclay do not seem to have resulted, although the decomposition of the lavas has often proceeded so far as to render it difficult to distinguish the product from some fine marly sediment. Pseudo-stratification has been developed through the flattening of particles during the process of decay; and sometimes it is only the recognition of amygdaloidal structure, or the association with less rotted kernels, that betrays the igneous origin of the resultant clay.

A fine section is seen in Yardfoot Burn, two miles north of Beith. Here it is plain that the weathering has been volcanic as well as post-volcanic in date. The tops of successive flows

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[1] F. H. Hatch, 'The Lower Carboniferous and Volcanic Rocks of East Lothian,' *Trans. Roy. Soc. Edin.*, vol. xxxvii, 1892, p. 119. E. B. Bailey in 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 127.

[2] H. J. Seymour in 'The Geology of North Arran, South Bute and Cumbraes,' *Mem. Geol. Surv.*, 1903, p. 176; and W. R. Smellie 'The Igneous Rocks of Bute,' *Trans. Geol. Soc. Glasgow*, vol. xv, pt. III, 1916, p. 353.

[3] E. B. Bailey in 'Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 125.

[4] 'Summary of Progress, 1918,' *Mem. Geol. Surv.*, 1919, p. 22.

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have been rotted by weathering, while the lower portions have been less altered.

East of Barrmill, two miles south-east of Beith, a still more striking demonstration of inter-volcanic weathering is afforded by thick beds of sediment in association with rotted flows some distance down in the lava-sequence. In the Lugton Water, for example, a completely rotted porphyritic basalt is succeeded by perhaps 40 ft. of volcanic detritus with subordinate entomostracan shales, and this is definitely overlain by a series of hard unaltered lavas of the top Jedburgh-Dalmeny groups.

In the part of the ground mapped by Mr. Bailey, the only good section illustrating the phenomena of weathering just described occurs along the course of the Gryfe Water at Bridge of Weir.

Economics.—Beds of oolitic ironstone have been mentioned above by Mr. Richey as occurring in the detrital zone overlying the Calciferous Sandstone lavas. They are exposed at two localities:—

(1) Gunshill Burn, 350 yards S.S.W. of Holehouse Farm, $1\frac{1}{4}$ mile S.S.W. of Dunlop. Thickness perhaps a few feet.

(2) Yardfoot Burn, 350 yards S.W. of Yardfoot Farm, 2 miles N.N.E. of Beith. Thickness, 2 ft. 6 in.

In the hand-specimen the rock consists of ooliths of hæmatite set in a fine-grained buff-coloured ground-mass. The proportion of ooliths to ground mass is about 1:1. The ooliths vary in size from small round grains up to nodules half an inch in diameter. Under the microscope (20027, 20079) they often show concentric growth-bands, where besides hæmatite some foreign matter can be recognised. The ground-mass is composed of detrital material with many quartz-grains, and is relatively poor in iron.

Analyses of material from Yardfoot have been kindly supplied by Mr. J. Gibson, of the Glengarnock Iron Works:—

	Nodules only. per cent.	Sample of Seam. per cent.
Iron	56·64	25·34
Insoluble Residue	9·7 (including 6·9 silica)	48·50

The insoluble groundmass robs the deposit of any present value.

Small concentrations of iron are also met with in connection with the Calciferous Sandstone basalt lavas rotted *in situ*. Specimens were collected from a pocket at the top of a rotted lava-flow in a railway-cutting on the Glasgow and Kilmarnock Joint Railway, $\frac{1}{2}$ mile E. of Barrmill Railway Station. For this Mr. J. Gibson kindly supplies the following analysis:—

	per cent.
Iron	36·14
Insoluble Residue	34·40 (including 19·00 silica)
Sulphur	0·144
Manganese oxide	0·18
Lime	0·25
Loss on ignition	7·70

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In this case again the high percentage of insoluble residue makes the deposit valueless.

Glacial.—Mr. Bailey finds that the merging of the high lava-country south of the Clyde estuary into the lower sedimentary territory farther east is accompanied by interesting glacial characteristics. Between the drift-free high ground and the more or less completely covered low ground there lies, at intermediate elevations, a certain amount of boulder-clay, everywhere disposed, between the Clyde and Bridge of Weir, in the form of isolated drumlins. These drumlins often stretch athwart the scarp-and-hollow featuring of the lavas they surmount. They commonly attain to 50 ft. in thickness. At the same time drumlins are by no means restricted to the intermediate belt; they are characteristically developed in the boulder-clay spread on the lower ground farther east.

Now the driftless nature of the high ground is probably connected with the rapid movement of the ice where it hurried forward, making up in pace for what it lacked in depth. We may take it then that the ice farther east was also moving rapidly, though not so rapidly as to preclude the deposit of boulder-clay. The drumlin form of the boulder-clay, manifest, as it is, in the first appearance of the deposit, favours one of two alternative suggestions. The discontinuous ice-motion, of which the drumlins are a register, may be:—

(1) A feature of a rapidly moving ice-sheet as such, or

(2) A feature of a rapidly moving ice-sheet where motion comes to be checked by increasing depth.

Of these the former seems perhaps more consonant with evidence from other quarters.

It should be remarked that the particular drumlins upon which the above conclusions are based, are not mere variants of crag-and-tail phenomena.

Farther south in the upland district extending to the east of Beith, the original survey demonstrated that the main glaciation came from the north rather than the south. During the present revision Mr. Richey has obtained abundant confirmatory evidence of this, including striated *roches montonnées* moulded by ice from north-east to south-west.

At Lugton, about four miles east of Beith, Prof. Gregory[1] has advanced evidence suggesting glaciation from S.W. to N.E. The glaciated surfaces seen by him have since been removed, but some 20 yards away in the same quarry there is now exposed indisputable evidence of glaciation from N.E. to S.W. The limestone quarried has an irregular top on which rests a bed of fireclay. This top has yielded during glaciation a number of miniature striated *roches montonnées*, of which the orientation is clearly defined.

[1] J. W. Gregory, 'Glaciated Rock Surface at Lugton, North Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xiii, pt. 1, 1907, p. 10.

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No additional area was revised during 1919 in the Central Coalfield, except that the igneous rocks described by Mr. Bailey and Mr. Richey to some extent enter into the marginal six-inch sheets on the west side of the coalfield around Paisley and Bridge of Weir. The revision of that coalfield is now completed so far as the coal-bearing strata are concerned, but considerable areas of the non-productive strata around the field require revision in order to complete the one-inch sheets; this is especially the case in South Lanarkshire (one-inch Sheet 23), of which about a half is as yet unrevised. The coalfields adjacent to the Central Coalfield now call for attention. Mr. Dinham has been at work in the district between Stirling and Denny and has paid special attention to the Lower Limestones, which are excellently exposed in the valleys of the Carron and the Bannockburn. Mr. H. H. Read has begun the revision of the Alloa Coalfield, which, occupying a position between the Fife Coalfield and the great Central Coalfield, forms an important connecting link and requires careful study, especially as regards the sequence and correlation of seams.

Douglas Coalfield.

In the Douglas Coalfield in South Lanarkshire which was being revised before the outbreak of war, no additional area has been revised, but the cores of many of the new bores now in progress have been examined by Mr. Macgregor and the correlation of the seams with those of the other coalfields of Lanarkshire and Ayrshire has been considered. Some of Mr. Macgregor's results are embodied in the following report.

During the past year our knowledge of the Carboniferous formation as developed in the important outlier of the Douglas Coalfield has been considerably increased, and more especially in regard to the Carboniferous Limestone Series. It has been possible, for example, to recognise in the Douglas area horizons which are well-known in the Central Coalfield, and to establish a definite correlation of the Coalburn sequence with that found to the north of the broad barrier of Old Red Sandstone rocks which stretches from Lesmahagow to Lanark. The discovery of *Posidonomya corrugata* in the limy shales immediately underlying the Top Macdonald Limestone, renders the correlation of the Macdonald Limestones with the Hosie Group a matter of certainty. Probable representatives of the Under Limestone and of the Basket Shell-bed of the Strathaven district have also been recognised. Attention has naturally been paid chiefly to the Limestone Coal Group, and the most striking feature it displays in this area is its great variation in thickness. In the Coalburn field, on the west side of the basin, it is from 55 to 66 fms. thick and is probably even less than this below the Millstone Grit of the Poneil area, but where it reappears at the surface on the east at Ponfeigh and Rigside it is nearly twice as thick. The increase is distributed throughout the whole sequence and affects barren strata and coals alike. The latter vary in thickness through-

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out the field, but are unquestionably thicker and more numerous on its eastern margin. The sections given in Fig. 1 bring this out clearly and show in addition the correlation of the seams wrought at Coalburn and at Ponfeigh. In establishing the correlation two thin blackband ironstones have proved of significance; the lower of these—above the Nine-foot at Coalburn and above the Kirkroad at Ponfeigh—is the more persistent and was formerly much wrought. These blackbands are sometimes developed merely as a few inches of irony parrot, but can generally be recognised on careful examination. The upper part of the sequence is in some cases interrupted by the occurrence of coarse gritty sandstones which cut out and replace one or more of the coals. So far as is known these are of local occurrence and the phenomenon is probably analogous to the 'wash-outs' found at Bankend and Dalquhandy in the workings of the Nine-foot Coal.

The sequence at Coalburn is similar to that found in the Muirkirk-Glenbuck area, and the names given to the chief coal and limestone horizons are for the most part common to the two fields. At Ponfeigh and Rigside, on the other hand, a local nomenclature is in use (*see* Fig. 1). The marine band that occurs some 7 to 16 fms. above the Top Macdonald (or Top Hosie) Limestone has been noted in many borings and forms a useful index-mark in obscure ground. It consists of 5 or 6 ft. of shelly impure limestone or limy fakes and corresponds to the well-known Johnstone Shell-bed of North Ayrshire and the Central Coalfield. Over the latter it has been traced from Paisley and Glasgow as far north as Denny and as far east as Bathgate and Wilsontown. The 'Black Metals' of the Central Coalfield are represented by the 4 or 5 fms. of black shales (blaes) containing nodules and thin ribs of clayband ironstone which occur between the Six-foot and Nine-foot Coals or, in the Ponfeigh sequence, between the Stony and Robb seams. The only fossils obtained as yet at this horizon are a few specimens of *Lingula* and in this the Douglas area agrees with the Glasgow and North Ayrshire districts, although at many places east of Glasgow—e.g., at Denny, Bathgate, Wilsontown, Carluke, East Kilbride, etc.—a definitely marine band is found in the 'Black Metals.' The associated claybands were formerly wrought to some extent at Bankend and Auchlochan, but are generally poorly developed in the Douglas field; they correspond to the Logan's Bands of Ayrshire, the California and Banton Claybands of Glasgow and Kilsyth respectively, the Hogg Fence Ironstones of Wilsontown and the Maggie Bands of Carluke, and occur upon the same horizon as the High-band and Mid-band Ironstones at Muirkirk. The coal which commonly underlies this series in the Douglas field is the equivalent of the Thirty-inch of Muirkirk and is wrought at Douglas Colliery under the name of the Back Seam; its equivalent in the Central Coalfield is no doubt the Upper Garscadden Blackband or the thin coal which so frequently takes the place of the latter. The Six-foot coal of Coalburn (or its equivalent, the Robb and Fallowhill of Ponfeigh) represents the Lesmahagow Main Gas,

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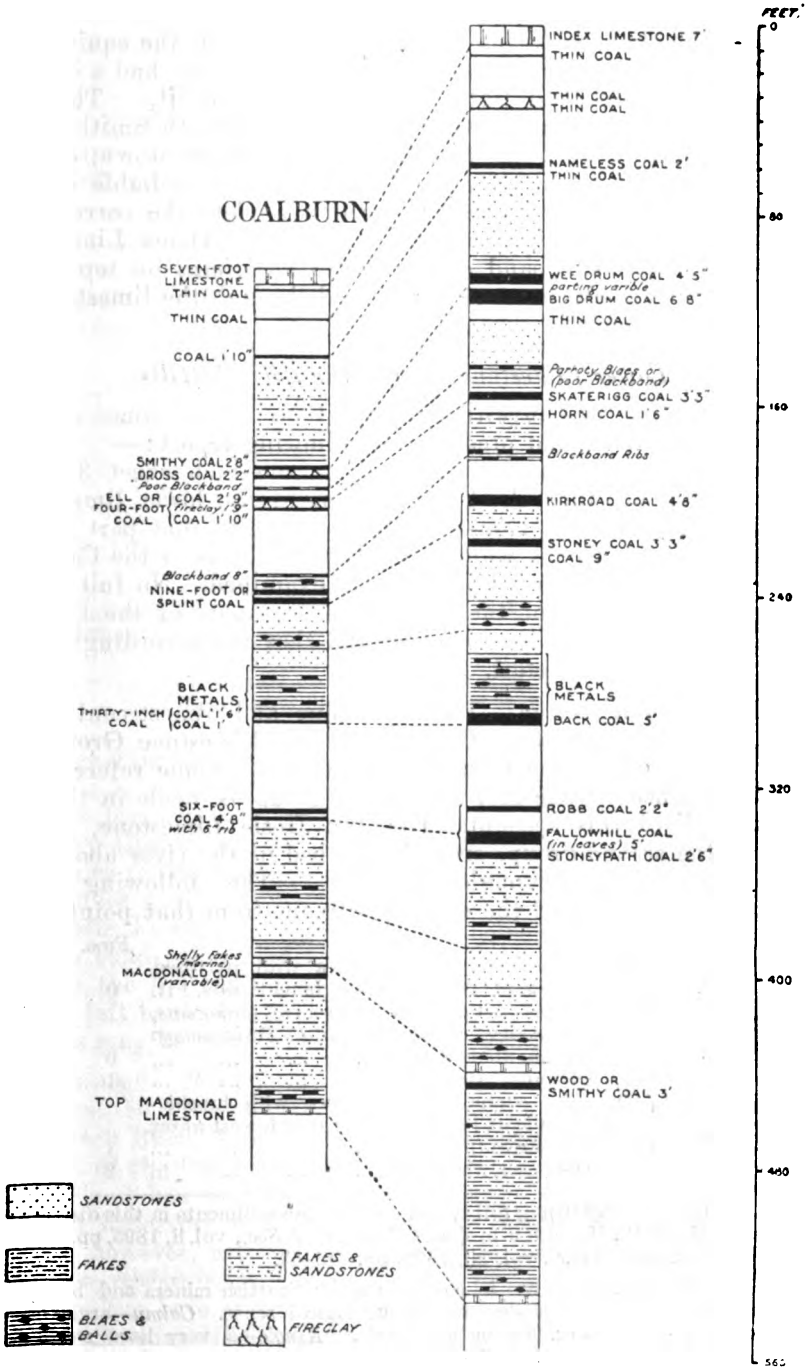
FIG. 1.—COMPARATIVE VERTICAL SECTIONS OF THE DOUGLAS COALFIELD.



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or Wilsontown Gas, Coal, and at Muirkirk is known as the Catchyburn. Both it and the Nine-foot above it contain ribs of cannel. The latter seam is apparently represented at Ponfeigh by two coals, the Kirkroad and the Stony, and corresponds to the Auchenheath Dross, Carluke Tower, or Wilsontown Main, Coal. The thin blackband above the Nine-foot is the equivalent of the Auchenheath Wee Gas Coal, which generally had a 3 to 5-inch rib of blackband ironstone associated with it. The Ell Coal again is possibly the same as the Auchenheath Smithy, the Lower Carluke Coal, the Fireclay Craw of Wilsontown, or the Jewel of Bathgate, although the absence of any reliable index-horizon in the upper part of the group renders the correlation of the higher seams somewhat doubtful. The Index Limestone has a characteristic band of *Productus latissimus* on top of it, and the same shell may occur scattered through the limestone or immediately below it.

Lower Limestones east of the Kilsyth Hills.

Mr. Dinham has investigated the Lower Limestones of the Bannockburn area and presents the following report:—

In the district between Bannock, in one-inch sheet 31, and Stirling, in one-inch sheet 39, sections of the lower limestones of the Carboniferous Limestone Series, and of that part of the Calciferous Sandstone which overlies the lavas of the Campsie and Kilsyth Hills, have been recently examined. No full report of the development of these strata in this part of the Central Valley appears to be in existence, and they are accordingly now described in some detail.[1]

River Carron section.—There is a fine and almost continuous section of the Limestone Coal and Lower Limestone Groups in the north bank of the Carron above Denny. Some reference to particular beds in the first-mentioned group is made in the last paragraph of this account. The Top Hosie Limestone, at the top of the second group, crops in the bed of the river about 170 yards west of Carronglen Cottage. The following is a generalised section of the strata upstream from that point:—

		Fms.	ft.	in.
Top Hosie.	Dark blue calmy[2] LIMESTONE with pyritised '*Bellerophon*,' *Naticopsis*, and brachiopods, 1 ft.	0	1	0
	Blue blaes with poorly preserved *Orthoceras*, *Sanguinolites costellatus*, and ? *Posidonomya corrugata*, about 4 ft.	0	5	0
	Obscured, about 5 ft.	1	4	0
Second Hosie.	Grey-blue encrinital LIMESTONE with brachiopods, at least 14 in. (visible only at lowest water in mid-stream)	1	5	2
	Obscured, about 2 ft....	2	1	2

[1] Accounts of the Stirling Sill and of some of the sediments in this district are given by Mr. H. W. Monckton in *Quart. Journ. Geol. Soc.*, vol. li, 1895, pp. 480–92, and in *Proc. Geol. Assoc.*, vol. xii, 1892, pp. 242–53.

[2] The following terms are in current use by Scottish miners and borers:—*Blaes*—mudstones, or shales in the geological sense. *Calmy*—argillaceous. *Fakes*—thin-bedded argillaceous sandstone. *Kingle*—a very hard sandstone, often with a limy cement. *Rib*—a thin layer. *Plies*—thin bands.

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		Fms.	ft.	in.
	Hard black sandstone, flaggy at top, about 29 ft.	7	0	2
	Fakes and fireclay, with thin coaly streak, 8 ft. ...	8	2	2
	Kingle with plant-remains, and markings like *Spirophyton* on its upper surface, 2 ft. ...	8	4	2
	Micaceous blaes, with a 3-in. band containing *Aviculopecten, Sanguinolites, Streblopteria*, etc., 1½ ft.	8	5	8
	Fakes and fireclay, 2½ ft.	9	2	2
	Blue blaes with irony ribs and *Orthoceras*, '*Bellerophon*,' and lamellibranchs, 5 ft. ...	10	1	2
? Main Hosie	Grey sandstone, locally ochreous, with encrinites, etc. (probably a decalcified Limestone), 2 ft.	10	3	2
	Obscured, about 5 ft.	11	2	2
	Sandstone and fakes, about 22 ft.	15	0	2
	Dark-blue blaes, faky at top, (under water) ? barren, about 12 ft.	17	0	2
Carron Kingle	Blue limy kingle, weathering like a limestone, with fish-teeth and ? entomostraca; no marine fossils, about 2 ft. 4 in.	17	2	6
	Fakes with sandstone-ribs, passing down into fakes, about 35½ ft.	23	2	0
	Light-blue faky blaes, with white worm-casts, a few marine fossils at the top, 6 ft.	24	2	0
	do. with pyritous pellets and rare encrinites, 26 ft.	28	4	0
	Hard blue flaggy fakes, 2 ft.	29	0	0
	Light-blue faky blaes, with pyritous pellets, and irregular rusty pyritous nodules increasing in size and number towards the base. Encrinites common at the very bottom, 20 ft.	32	2	0
Fankerton Limestone	Limestone with indistinct encrinites, grey and greenish, 2 ft.	32	4	0
	Hardened grey blaes, about 1 ft....	32	5	0
	Limestone, grey and blue, 2 ft. 6 in.	33	1	6
	White crystalline hardened sandstone, about 10 ft.	34	5	6
	Inaccessible, about 6 ft.	35	5	6
	Top of big dolerite-sill	–	–	–

The last-mentioned strata are marmorised and otherwise intensely altered by the underlying intrusion. This sill, which 1½ miles to the north-east is known to be at least 280 ft. thick, continues upstream in the sides of the river until it meets the Campsie Fault, or its continuation, about 150 yards east of a sharp bend below Garvald Mills. There it is thrown altogether above the low right bank, but appears at the very top of the steep left bank, where isolated exposures of ashy sandstones and shales may be seen between it and the Calciferous lavas beneath.

Bannock Burn section.—The strata described in the generalised table which follows, crop out in the valley of the Bannock Burn, 4 to 5 miles S.S.W. of Stirling and about 4 miles N.W. of the Carron section. The greater part is exposed in the bank and bed of the stream about a mile S.W. of the North Third Reservoir of the Grangemouth Water Works; the highest beds, however, are seen only in the (south) Sauchie Craigs east of the reservoir, being cut out at the other exposures by the descending base of the sill which forms the Craigs. This intrusion, like that of the bottom of the Carron section, is a continuation of the Stirling Castle and Abbey Craig Sill.

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		Fms.	ft.	in.
Bottom of dolerite-sill		–	–	–
	Pale-blue blaes, altered near the sill, with numerous pyritous pellets; larger irregular pyritous nodules near the base; occasional encrinites at the bottom, up to 26 ft.	4	2	0
BANNOCK "A" & "B" LIMESTONES.	Blue partly decomposed encrinital LIMESTONE, 2 ft. 6. in	4	4	6
	Barren blue blaes, 1 ft. Obscured strata, 1 ft. ...	5	0	6
	Blue LIMESTONE with mottled fracture; irregular 'ooliths,' up to more than an inch in diameter, show on the weathered surface. No marine fossils seen. 1 ft. 7 in.	5	2	1
	? Sandy marl, or decomposed dolerite ? 2 ft. 6 in.	5	4	7
	Greenish baked nodular fireclay ?; locally fakes with some blaes, 5 ft. 8 in.	6	4	3
	Sandstone (locally a ganister) and fakes 4½ ft. ...	7	2	9
	Blue crumbly blaes, apparently barren, 6 ft. ...	8	2	9
	Sandstone-posts and ribs, with fakes, 9 ft. ...	9	5	9
	Blue blaes with traces of plants, 1 ft. 6 in. ...	10	1	3
	Black platy blaes, with athyrids, productids, *Lingula*, and a lamellibranch, 4 in.	10	1	7
BANNOCK "C" LIMESTONE	Hard blue encrinital LIMESTONE decalcified, with abundant marine fossils at top and bottom, 3 ft. 5 in.	10	5	0
	Bright COAL 5 in., on soft fireclay 5 in.	10	5	10
	Rubbly sandstone, and sandstone fakes, 19 ft. ...	14	0	10
BANNOCK "D" LIMESTONE	(Obscured by old workings, which extend along the whole length of the sections, 16 to 20 ft.)	17	0	10
	Blaes with small crystals of gypsum, 2 ft.. ...	17	2	10
	Blaes with regular pyritous ribs, 3 ft.	17	5	10
	Blaes with gypsum, 1 ft. 2 in.	18	1	0
	Papery blaes with strongly curved bedding, 1 ft. ...	18	2	0
	Blaes with lenticles of clayband ironstone; entomostraca and fish-teeth at base, 1 ft. 8 in.	18	3	8
	Blaes with 3 in. limy clayband and occasional marine fossils, 1 ft. 9 in.	18	5	5
BANNOCK "E" LIMESTONE	White and yellow LIMESTONE:—nodular with large encrinites, and coaly films at top, 2½ ft.; more nodular, with lamellibranchs, gastropods, *Fenestella*, rod-like bryozoa and a doubtful coral, 2 ft.; faky and nodular, 1 ft. Total 5½ ft.	19	4	11
	Blaes and limestone-bands, with brachiopods, 2 ft.	20	0	11
BANNOCK "F" LIMESTONE	Grey slabby LIMESTONE, composed of harder and softer bands. Top 3 in. locally slightly nodular, remainder very fossiliferous (encrinites, *Archaeocidaris*, *Tabulipora scotica*, and brachiopods. No corals noticed), 2 ft. 2 in.	20	3	1
	Blue micaceous blaes with a 6-in. clayband. *Lingula* and fish-remains locally, 2 ft. 2 in. ...	20	5	3
	Ashy marl or mudstone (locally blaes with plant remains), 1½ to 3 ft.	21	1	6
	Ashy sandstone often quite green, hard or soft, 3 to 6 ft.	21	5	6
	Ashy fakes and blaes (locally a coarse detrital ash), with ashy sandstone-ribs at bottom, 7 to 9 ft.	23	1	6
	Blue thin blaes, apparently barren; ribs of fakes and ? pyritous ironstone in bottom half. 13½ ft.	25	3	0

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		Fms.	ft.	in.
Bannock "G" Limestone	Limestone: faky, with exceedingly abundant fossils, including giganteid *Productus*, *Lithostrotion* and a clisiophyllid coral, 3 in.; compact, locally lenticular, with brachiopods, 6 in.; faky, with abundant fossils (encrinites, brachiopods, large productids lying on their ventral valve, '*Euomphalus*,' lamellibranchs, and a zaphrentid coral), 9 in. Total, 1 ft. 6 in. ...	25	4	6
	Blue blaes, partly ashy; at base a thin layer of ? mother-of-coal with cone-in-cone structure, 2 ft.	26	0	6
	French-grey mudstone or ashy marl, 1½ to 3 ft. ...	26	3	0
	Line of discordance.			
	Bedded variegated detrital 'ash,' with nodules of hard chocolate 'marl'; the beds are clearly truncated by the overlying stratum, about 20 ft.	29	5	0
Lavas of the Kilsyth Hills		–	–	–

The Bannock "D" Limestone must be the "Murrayshall Limestone" formerly wrought at Cambusbarron, 1½ miles W. of Stirling, at Murrayshall, 2 miles S.W. of Stirling, and at Craigend and Touchadam, north of the Reservoir. No section of this seam or of the adjacent strata is now exposed, but according to a century-old record[1] the limestone at Murrayshall was a bluish-black seam 6 ft. thick, with "entrochi" (encrinites) and specks of pyrites, lying in the middle of not less than 35 ft. of dark blaes, partly limy at the bottom. A 3-ft. limestone, 42 ft. above the main seam, rested on 4 ft. of blaes mixed with coal, and thus appears to correspond to "C," the only limestone beneath which a coal has been noticed.

Correlations.—Comparison shows that the above sections cannot be matched with each other, except that the Fankerton Limestone of the Carron resembles the Bannock "A" and "B" Limestones taken together. The intense alteration produced by the intrusion prevents a detailed comparison of the beds, but in each case we have two limestone-seams separated by a foot or so of blaes, lying above more or less sandy strata and beneath several fathoms of blaes which, alike in thickness and in the lithological peculiarities described, differs from any other beds of blaes in the sequence at either place. It is accordingly natural to consider these limestones as equivalent, and this identification leads to consistent results.

In correlating these exposures with the sections at Campsie and Kilsyth, there can be no doubt that the two highest Carron Limestones are the Top Hosie and the Second (or Mid) Hosie[2]. The decalcified limestone in the Carron may be the Main Hosie of the Hurlet District, formerly seen (now quarried away), also in the Burniebrae Burn ("Shields Burn"), Campsie, east of Shields steading, at a horizon about 4 fms. below the Second Hosie. The thick blaes above the Fankerton Limestone resembles that

[1] Lt.-Col. Imrie, *Mem. Wernerian Soc.*, vol. ii (1818), pp. 28, 34, 50, and plate.

[2] Together, the 'Hosie Limestone' (in 2 beds) of Macnair and Conacher, *Trans. Geol. Soc. Glasgow*, xv, part i, (1912–13), pp. 43 and 48, and the Bellerophon, or Hosie, Limestone of 'The Geology of the Glasgow District,' *Mem. Geol. Surv.*, 1911, p. 24.

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which overlies the Blackhall[1] at Corrie and in the lower part of the Burniebrae Burn. As Mr. Carruthers points out, the non-marine, "oolitic," nature of the Bannock "B" Limestone is exactly comparable to that of the lower part of the Blackhall Limestone[2], an observation which confirms the conclusion already reached as to the identity of the Fankerton with the Bannock "A" and "B" Limestones. Limestone "C" will then represent the sandy encrinital limestone of Campsie[3], and "D" will be the Hurlet, so that the prevailing identification of the latter with the Murrayshall Limestone remains unchanged. Certain resemblances between the remaining Bannock Limestones and the Corrie section at once suggest themselves; whether the differences from both Corrie and Touchadam (*see below*) are due to lateral variation, to local unconformity, or to both causes combined has yet to be investigated, but the following remarks, extracted from a report by Dr. G. W. Lee on the fossils recently collected from the Bannock section, must be taken into consideration in any correlation.

(1) Blaes below Limestone "D."—These beds contain abundant *Sanguinolites costellatus*, with *Myalina verneuili*, *Euphemus urei*, and a goniatite—all members of the "Abden Fauna," below the Hurlet Limestone.

(2) Limestone "E."—This bed also contains *Productus pugilis* in abundance, *Productus youngianus*, and bands of Bryozoa (*Rhabdomeson*). These faunal characteristics are strongly marked in the White Coral Limestone (to the exclusion of other horizons) at Corrieburn, a seam which the Bannock "E" Limestone closely resembles also in general aspect. All the palæontological and lithological evidence points to the equivalence of these two limestones.

(3) Limestone "F."—There is nothing distinctive in the fauna of this limestone.

(4) Limestone "G."—This is characterised by the abundance of giganteid *Producti*, which, with single and compound corals (*Syringopora*, *Lithostrotion*, *Diphyphyllum*) and other fossils, constitute an assemblage quite typical of the Hollybush limestone fauna, as represented in the Survey collections from the Hollybush district. There is nothing like it in the Corrieburn section.

One result of the above comparisons is that, the Fankerton Limestone being no longer regarded as the Hurlet, the consequent absence of the true Hurlet and of the lower seams from the Carron Section is to be ascribed to faulting, as already mentioned, probably combined with a descent of the sill, on the

[1] Blackhall Limestone, Glasgow *Memoir*, pp. 22–24; Baldow Limestone of Macnair and Conacher, *loc. cit.*, p. 46; Black Limestone or 'Hosie Limestone' (of Campsie) in Glasgow *Memoir*, p. 23; in John Young, *Trans. Geol. Soc. Glasgow*, i, 1860, p. 27, and do., 3rd ed, 1894, p. 42; in J. Neilson, *ibid.*, xiv, pt. iii, 1911–12, p. 327 footnote, pp. 328–333; etc.

[2] Macnair and Conacher, *loc. cit.* pp. 46 and 49 ('q'), Glasgow *Memoir*, pp. 23 and 24.

[3] Exposed in Cowies Glen (part of the 'Shields Burn'), *see* Glasgow *Memoir*, p. 23; also in the Baldow Glen, etc. This is the 'Shields Bed' of Macnair and Conacher, *loc. cit.*, pp. 45 and 47. It does not yet appear to have been recorded from Corrie.

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upstream side of the fault, to a lower stratigraphical horizon. The latter phenomenon is suggested by a bore through the sill near Quarter, which reached the lavas without any record of limestones or of more than a few feet of normal clastic sediment.

The Touchadam Section.—Farther down the Bannock Burn, ⅔ mile below the Reservoir, in the stream at Touchadam Quarry, other sections of lower limestones are exposed in a small syncline. They show such differences from those higher up the Burn that they cannot yet be satisfactorily correlated. The Murrayshall Limestone has been taken out both at the quarry and beneath the crags on the opposite side of the stream where, near the old level, and about 5 ft. below the big sill, a 38-in. seam with abundant *Lithostrotion* rests on a thin ashy bed (? white trap) above 18 ft. of sandstone overlying 12 ft. of barren blaes. This appears to be the Bannock "C" Limestone. Below the Murrayshall Limestone, of which numerous fragments remain in a waste-heap in the quarry, the following sequence can be made out:—

		Fms.	ft.	in.
Murrayshall Limestone	... ...	–	–	–
	? Gap., 0 to about 19 ft.			
	Blaes with *Lingula* and entomostraca, 6½ ft. ...	1	0	6
	Black blaes with fireclay and thin ribs, uneven bedding, 11 in.	1	1	5
	Blaes with *Lingula* and a small lamellibranch, 1 ft. 2 in.	1	2	7
	Fireclay and blaes, 9 in.	1	3	4
	Slaty blaes with *Orthoceras*, goniatites, *Euphemus*, *Sanguinolites costellatus* and entomostraca, 1 ft. 4 in.	1	4	8
	Softer blaes with similar fossils: ironstone-ribs with entomostraca near bottom, 3 ft.	2	1	8
	Blaes with *Lingula*, entomostraca, and two crystalline LIMESTONE ribs, 2 ft. 4 in.	2	4	0
	Pale variegated marls and ashy mudstones with limy nodules, 27 ft.	7	1	0
	Blaes with *Lingula*, 1 ft. 10 in.	7	2	10
GONIATITE-LINGULA LIMESTONE	Slabby LIMESTONE and limy blaes with abundant goniatites and *Lingula*; *Orthoceras gesneri*,[1] lamellibranchs, and fragments of brachiopods. Two ribs of encrinital limestone below the middle, 4 ft. 2 in.	8	1	0
	Blaes with gypsum-efflorescence, pyritous rib near base, 7½ ft.	9	2	6
	Pale marl or ashy mudstone, 9 ft.	10	5	6
	Obscured, about 10 ft.	12	3	6
	Blaes and faky blaes, more or less ashy, about 13 ft.	14	4	6
PRODUCTUS LIMESTONE	LIMESTONE and limy blaes with abundant large *Productus*, about 3 ft.	15	1	6
	Pale ashy blaes, up to 2 ft.	15	3	0
	Bedded chocolate and green 'ash' and marls, ? 30 ft.	20	3	0
Lavas	... ...	–	–	–

[1] A rare fossil recorded previously in Scotland at South Cobbinshaw (from the Raeburn, formerly Mungle, Shell Bed. *See* 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 1912, p. 94), and at Craigenglen; also from the Upper Limestone Group.

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The width of the syncline measured between the two crops of the Productus Limestone, is about 150 yards. It is traversed by several small faults, one of which, with a gentle hade and a southerly downthrow of 10 ft., complicates the cliff-section in the left bank, and repeats the crop of the Goniatite-Lingula Limestone in the stream on the southern limb of the fold.

The continuous line of quarries from Touchadam right up to the higher part of the Bannock Burn must surely be in the same seam, viz., the Murrayshall Limestone. If further the Productus Limestone corresponds to "G," the Goniatite-Lingula Limestone to "F," and "E" be represented by part of the 27 ft. of variegated marls with limy nodules, as Mr. Tait suggests, we have then an example of lateral variation which well illustrates the difficulties of correlation among the lower Carboniferous limestones.

Dr. Lee reports that the Goniatite-Lingula Limestone contains a rich assemblage, not represented in the Corrieburn section, which has many points in common with the Basket Shell Bed exposed at Cot Castle near Strathaven. Among these are the abundance of goniatites (including ?*Dimorphoceras*), *Orthoceras*, and brachiopods, and the presence of several kinds of lamellibranchs (including *Cypricardella rectangularis*).

Other exposures.—At Old Sauchie, 1½ miles E. of the Reservoir, the Bannock section is seen again, from the blaes above Limestone "A" to the coal beneath "C." One mile W.S.W. of this point, a disturbed section of quarried limestones is seen in a "window" through the dolerite, on the north side of an east-and-west fault which runs along the Auchenbowie Burn. Immediately south of this fault sandstone, and some blaes with marine lamellibranchs, are seen below the sill; but no limestones are exposed, nor are there any lines of old workings to the southward, and it seems probable that, between the Auchenbowie fault and the point where the Campsie Fault crosses the Carron, the dolerite occupies a stratigraphical horizon lower than it does beyond those limits. It is to be noted that it is only within the same limits that there are conspicuous limestone workings *above* the sill, at Northfield and in the burn west of Quarter; these are presumably also in the Murrayshall ("D") Limestone, but there is no definite evidence on this point.

The Top Hosie with *Posidonomya corrugata* is still exposed at the south end of some old workings in the Chough Glen[1], where the Second Hosie was probably taken out at the same time. These two limestones are also exposed in the Castlerankine Burn near Linns[2], while higher upstream and close to the boundary-fault, a different, decomposed seam, may possibly be the Main Hosie. Further down the same burn, about half-a-mile W. of Rashiehill, the Top Hosie is again seen, and 200 yards from the steading a thin band of marine fossils, at the bottom of a small

[1] 'Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, pp. 62 and 68, locality 194.

[2] *Ibid.* Locality 185.

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cliff of blaes, is probably the position of the Johnstone Shell Bed[1] which is faulted out of the Carron Section. The marine band in the "Black Metals," at a still higher horizon, is exposed in the Carron opposite the Herbertshire Paper Mill[2]. It consists of 3½ ft. of fossiliferous blaes, and the band of crushed *Naiadites*, found also at other localities a few feet higher in the sequence, is conspicuous at the same spot.

Many bores which are being put down in the coalfields and oil-shale fields have been visited by Dr. Lee. Two recently put down at Blackness, Linlithgowshire, in search of a north-western extension of the oil-shale fields of Linlithgowshire, have shown the absence of workable oil-shale in that district. The sequence is remarkable in the attenuation of the oil-shale strata between the Broxburn and the Pumpherston horizons. Particulars will be found in Appendix II. We are especially indebted to Mr. James Kidd, M.P. for Linlithgowshire, for permission to publish the results of these bores.

(3) Boring for Oil at West Calder.

The bore in search of petroleum which is situated about a quarter of a mile south of the village of West Calder, Midlothian, has now reached a depth of 543 fathoms, and is the deepest bore which has yet been put down in the Oil-Shale Series in Scotland. The West Calder district is included in six-inch Sheet Edinburgh 11 N.W., published in 1908, but of which a new edition is in preparation. A small anticline occurs to the south-west of West Calder and the oil-bore has been placed approximately on the summit of this anticline, which is about half-a-mile in diameter and gives place to synclines on the east and south. The important Calder fault has been traced on the east side of the anticline, but perhaps dies out as it runs south-westwards, as the dislocation of the outcrops of the oil-shale seams cannot be of great magnitude. At a distance of about half-a-mile to the south-west of the bore there are several small faults.

The bore starts immediately below the Broxburn Shale which has been mined to the outcrop a short distance to the west. At a depth of 50 to 55 fms. it passes through an oil-shale which is recognised by the mining engineers of the district as the Dunnet seam. About 73 fms. from the surface there is another oil-shale, which is probably the Under Dunnet, well known in the adjacent district[3], but frequently not of economic value. Thirty fathoms lower down there is a light-brown fresh-water limestone with entomostraca, apparently 10 to 12 ft. thick. This may be the Barracks Limestone, though that bed is

[1] 'Top Marine Band' of P. Macnair, 'The Hurlet Sequence,' etc., *Proc. Roy. Soc. Edin.*, vol. 38, pt. ii, 1917, p. 185.

[2] 'Explanation of Sheet 31,' pp. 62, 68 and 69, locality 192.

[3] 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 21.

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generally not well represented at West Calder. In other respects the upper portion of the bore does not differ from the sections recorded in other bores in the immediate vicinity. The deeper strata, however, have not been proved hitherto by boring at West Calder and the new record is of interest, not only as furnishing evidence of the exact geological sequence, but as differing somewhat from natural exposures in the neighbourhood.

The first recognisable horizon below the Barracks Limestone is the Burdiehouse Limestone, which was 15 ft. thick and was entered at 215 fms. It shows the usual characters, being a dark-coloured, fine-grained, fresh-water limestone. Between these limestones there are 110 fms., mainly sandstone with intercalations of dark shale, but although a thin oil-shale was found at 188 fms., there is no indication of any deposit of economic interest, and in the Camps Shale position above the Burdiehouse Limestone nothing of value was met with. For 63 fms. below the Burdiehouse Limestone there was a rather monotonous sequence of dark carbonaceous shales with a few beds of sandstone near the top, some marls and a thin dark limestone.

At 280 fms. a thick bed of greenish volcanic ash was encountered and this persisted to a depth of 418 fms. As a whole this ash-bed was uniform in composition, but occasionally it had an admixture of dark shale and at 375 fms. the rock-powder extracted from the bore showed traces of coal. The larger fragments in the ash were examined microscopically and proved to be olivine-basalt. From 418 to 433 fms. the bore passed through black shales, with a thin non-fossiliferous limestone of the type known in this district as a 'cement.' There another basaltic ash-bed was proved which persisted from 433 to 489 fms. Apparently it was free from admixed sediment. Below this there were 7½ fathoms of vesicular dark-green olivine-basalt, in a single lava-flow so far as was ascertained. From the base of this lava at 497 fms., black shales with a few thin seams of limestone or 'cement' extend to the bottom of the bore, a farther depth of 46 fms. The distance below the base of the Burdiehouse Limestone (217 fms.) is at present 326 fms., and is almost entirely occupied by black shales, basaltic ash-beds, and one lava-flow. None of the oil-shale seams that lie below the Burdiehouse Limestone, such as the Pumpherston, Dalmahoy, Wardie and Coalheugh Shales have been identified, but this was not unexpected as in no part of the surrounding country have they proved to be workable.

From a geological standpoint the striking feature of the bore record is the general character of the sequence below the Burdiehouse Limestone. In the nearest available section, that seen in the Murieston Water from Harburn to Skivo (from 2 to 4 miles distant) the sequence at this horizon consists largely of sandstone, with one oil-shale (the Coalheugh Shale), a limited amount of black carbonaceous shale and probably a few insignificant ashy beds[1]. Three miles to the south, in the Cobbin-

[1] 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 27.

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shaw district, these lower beds have been proved by bores and are visible in natural exposures. In that district the Pumpherston Shales are not workable, but there is a bed of volcanic ash, known as the Crosswood Ash, which may be on the same horizon as that which occurs in the West Calder bore. It is only 7 fms. thick, while in the bore under discussion there are 194 fms. of basaltic ash. At Crosswood also there is no lava-bed below the ashes. Other points of difference are that in the Cobbinshaw area there are frequent deposits of sandstone and shaly sandstone, a few thin encrinital limestones and intrusive sills of dolerite among the strata below the Burdiehouse Limestone, all of which are absent at West Calder, so far as the bore has yet proved.

III.—PETROGRAPHICAL WORK.

The work carried out in the Petrographical Department during the past year has been mainly connected with the preparation of a memoir on the petrography and chemistry of certain refractory materials, which is now in the press. Dr. Thomas has continued his work for the Research Department of the Admiralty and has reported upon matters of economic importance to Government departments and many private individuals. At the request of the Home Office, he furnished reports upon the microscopical and mineralogical characters of dust aspirated under special conditions from ganister-mines and other underground workings, after examination of some 50 samples.

The petrographical work connected with the survey of the Island of Mull, Moor of Rannoch and Ayrshire has been continued, and the study of the interesting xenolithic and sapphire-bearing composite sills of Mull has been resumed.

The petrography of the igneous rocks of Croft and adjoining areas has been undertaken by Mr. Whitehead for the memoir on the New Series Sheet 169 (Coventry).

The detailed petrography of Sheet 86, Scotland, is being dealt with by Mr. Read, and considerable progress has been made.

IV.—CHEMICAL WORK.

With reference to the work done in the laboratory, Mr. Ennos reports that the analyses of silica rocks and dolomites referred to in last year's 'Summary of Progress,' have been incorporated in 'Special Reports on the Mineral Resources of Great Britain,' Vol. XVI, which is now in the press. The analysing of a series of fireclays, 12 of which have been completed, has been commenced for another volume of these reports. Partial analyses of four iron-ores were made for Vol. XII of the reports, which deals with the iron-ores of Mesozoic and later formations. Three Scottish rocks previously examined for alkalis only, and a mineral from Ayrshire approximating in composition to kaolinite, have been analysed with the following results:—

Tourmaline-granite (pegmatite).—Vertical dyke in schists. Banffshire coast, west side of East Head, three-quarter mile

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north-east of Portsoy. One-inch sheet 96. Six-inch Banff. 4 N.W.

Slice No. S. 19628. Lab. No. 550.

Felspar-rock.—Vertical dyke, intrusive in Lewisian gneiss. Roadside at Cnoc an Tuir, halfway between Rhiconich and Achriesgill, north-eastern shore of Loch Inchard. One-inch map 113. Six-inch Sutherland 22 S.W.

Slice No. S. 19644. Lab. No. 552.

Large granite intrusion. Corrennie Quarry at Tillyfourie Railway Station, Aberdeenshire. One-inch map 76. Six-inch Aberdeen 63 S.E.

Slice No. S. 19626. Lab. No. 554.

Lab. No.	550	552	554
SiO_2	72·69	72·10	75·43
TiO_2	trace	trace	·32
Al_2O_3	14·46	15·14	13·06
Fe_2O_3	·72	·63	·69
FeO	not found	·05	·28
MnO	·10	·06	·11
CaO	·28	·27	·92
MgO	·03	·03	·12
K_2O	8·90	9·35	5·09
Na_2O	2·48	2·05	3·85
Li_2O	not found	not found	trace
H_2O at 105° C.	·05	·05	·06
H_2O above 105° C.... ...	·23	·21	·20
P_2O_5	·23	·10	·07
Total	100·17	100·04	100·20

Anal. E. G. Radley.

Mineral in veins in Bauxitic Fireclay. Saltcoats shore, Ayrshire. 1 in. sheet 22. 6 in. Ayr. 16.

Museum No. 12138. Lab. No. 604.

	Lab. No. 604.	Kaolinite $H_4Al_2Si_2O_9$.
SiO_2	45·35	46·60
TiO_2	·16	—
Al_2O_3	39·13	39·49
Fe_2O_3	·86	—
FeO	not found	—
MnO	trace	—
CaO	·03	—
MgO	·20	—
K_2O, Na_2O	trace	—
H_2O at 105° C.	·43	—
H_2O above 105° C. ...	14·12	13·91
P_2O_5	·10	—
Total	100·38	100·00

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V.—PALÆONTOLOGICAL WORK.

England and Wales.

New ammonites and other fossils obtained by Mr. Pringle from borings in Norfolk have added materially to our knowledge of the Kimmeridge Clay and its zonal characterization. The subzone of *Saccocoma*, as indicated by the presence of the name-fossil, was recognised in the Virgatites Beds at localities near King's Lynn. The pyritized radial plates of *Saccocoma*, first found at this horizon in Kent and later in Dorset, have now been proved to have a wide distribution and to provide an important datum-line easily recognisable in borings.

The identification of certain fossils obtained from the Llanfyllin district has shown that the palæontological evidence is essential to the correct geological mapping of that area.

Some ammonites collected by Dr. Kitchin and Mr. Pringle from below the Interruptus Zone of the Gault south of Leighton Buzzard have been added to the Survey collections. They comprise species of *Leymeriella* and *Sonneratia*, which characterize the zone of *Leymeriella tardefurcata* (d'Orb.) in parts of France and Germany. The development of this zone in England had not been previously recorded, although attention had been drawn to its absence in Kent and in the Boulonnais.[1]

Much revision-work was carried out in the Museum by Mr. Allen before his retirement. He transferred to the exhibition-cases many type-fossils and other specimens formerly in the collection of the Geological Society.

The following specimens in the Museum have been figured and described:—

In the Palæontographical Society's Volume for the year 1917. (Published 1919).

A Monograph of the British Palæozoic Asterozoa.

By Dr. W. K. Spencer, M.A.

Platanaster ordovicus *Spencer*, text-figs. 114–118, 120, 121, p. 171.

The Fossil Fishes of the English Wealden and Purbeck Formations.

By Dr. A. Smith Woodward, F.R.S.

Pholidophorus ornatus *Ag.*, pl. xxi, fig. 4, pp. 103–105.

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[1] 'The Faunal Characters and Correlation of the Concealed Mesozoic Rocks in Kent,' Appendix i, in 'Summary of Progress for 1918,' *Mem. Geol. Surv.*, 1919, p. 45.

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A Monograph of the British Cambrian Trilobites.

By Mr. P. Lake, M.A.

? Eurycare sp., pl. xi, figs. 6–8, p. 94.
Peltura scarabæoides (*Wahl.*), pl. xi, figs. 9, 10, p. 97.
„ olenoides (*Salt.*), pl. xii, fig. 4, p. 100.
Beltella depressa (*Salt.*), pl. xii, figs. 6–8, 10, p. 104.
„ verisimilis (*Salt.*), pl. xiii, figs. 2, 2a, 3, p. 107.
Parabolinella simplex (*Salt.*), pl. xiii, fig. 6, p. 110.
Angelina sedgwicki *Salt.*, pl. xiv, fig. 1, p. 112.
Dikelocephalus discoidalis *Salt.*, pl. xiv, figs. 2–5, p. 115.
„ celticus *Salt.*, pl. xiv, figs. 8–10, p. 116.

In the Geological Magazine, Vol. VI, 1919.

By Mr. R. G. Carruthers.

Cryptophyllum hibernicum *R. Carr.*, pl. xi, figs. 1–4, 6, p. 436.

In the Transactions of the Royal Society of Edinburgh, Vol. LI.

The Forest of Wyre and the Titterstone Clee Hill Coal Fields.

By Dr. R. Kidston, F.R.S.

Cingularia typica *Weiss*, pl. i, figs. 2, 2a, p. 1042.
„ cantrilli *Kidst.*, pl. i, figs. 3, 3a, 4, 4a, 5, 5a, p. 1045.
Sigillaria reticulata *Lesqx.*, pl. ii, figs. 1a-c, p. 1055.
„ transversalis *Brongt.*, pl. ii, figs. 2, 3, 3a, 4, p. 1054.
„ pringlei *Kidst.*, pl. iii, figs. 1, 1a, p. 1053.
„ nudicaulis *Boulay*, pl. iii, figs. 2, 2a, p. 1050.
„ *cf.* „ pl. iii, figs. 3, 3a, p. 1051.
„ candollei *Brongt.*, pl. iv, figs. 1, 1a, 2, 2a, p. 1049.
„ boblayi *Brongt.*, pl. iv, figs. 3, 3a, p. 1048.
„ distans *Sauveur*, pl. iv, figs. 4, 4a, p. 1051.
Lepidophloios acerosus (*L. & H.*), pl. ii, fig. 5, p. 1057.
Annularia spicata (*Gutbier*), pl. ii, figs. 6, 6a, 7, 7a, p. 1039.
Carpolithes areolatus (*Boulay*), pl. v, figs. 1, 1a, p. 1062.
„ membranaceus *Göppert*, pl. v, figs. 8, 9, p. 1060.

Contributions to our knowledge of British Palæozoic Plants.

Part I, Fossil plants from the Scottish Coal Measures.

By Dr. R. Kidston, F.R.S.

Sigillaria elegans (*Sternb.*), pl. iii, figs. 8, 8a, p. 711.

In the Journal of the Cincinnati Society of Natural History, Vol. XXII, No. 2.

Notes on Richmond and Related Fossils.

By Dr. Aug. F. Foerste.

Orthis (Dinorthis) retrorsa *Salt.*, pl. ii, figs. 1a, b, c, p. 48.
„ („) inflata *Salt.*, pl. ii, fig. 1d, p. 48.
„ (Hebertella) llandiloensis *Foerste*, pl. ii, figs. 1e, f, g, h, ; pl. iii, figs. 3, 3a, 3b. p. 49.

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Scotland.

Fossils were collected chiefly from the Carboniferous Limestone areas of Ayrshire, which are now undergoing revision. Several borings were visited and portions of cores were also sent to the Office by coal-masters, with requests for information, which it was possible to supply.

Since resuming palæontological work Dr. Lee has been engaged principally in revising existing exhibits and preparing new material for exhibition in the Survey Gallery of the Royal Scottish Museum.

VI.—PHOTOGRAPHIC WORK.

No photographs were taken in England and Wales owing to the absence of the photographer on military duty.

In Scotland 175 photographs were taken in illustration for the geology of the Argyll, Ayr, Forfar, Aberdeen and Banff districts.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

Although nominally closed during the greater part of the war, the Museum has been open to all who had definite enquiries to make. It was reopened to the public on April 1st, 1919, but the open evenings have been changed from Saturdays and Mondays to Saturdays and Thursdays. The mineral, fossil and rock-galleries are now accessible, but it has not been possible to bring up the ground-floor exhibits to their normal condition.

Exhibits of refractories, of rocks yielding oil and of natural oils have been prepared, and a series illustrative of chrysotile asbestos from South Africa and Canada. Examples of iron-ores, collected during the previous year, are being incorporated in a revised exhibit of British Iron-Ores.

A selection of stones suitable for war memorials was lent to the War Memorial Exhibition held at the Victoria and Albert Museum, and later at the Royal Academy. Many enquiries have been received on the subject of stones for memorials.

List of Donations during the year 1919.

Andrews, C. T., Esq.—Group of quartz-crystals from Congonhas de Campos, Minas Geraes, Brazil.

Ashcroft, F. N., Esq., M.A., F.C.S., F.G.S.—A series of minerals from Derbyshire and Cumberland. A series of specimens of zeolites.

Ashcroft, Miss M. E. M.—Dark-purple fluor containing a crinoid.

Dick, Allan B., Esq.—Four specimens of slags, silica from Cornwall.

Fitzmaurice, C. E. A., Esq.—Antimony and silver-lead ores from the Trevinnick Mine, Cornwall.

Gilbert, C. J., Esq., F.G.S.—Sun-cracks on sand-rock from the High-level Gravels at Little Heath, Berkhamsted.

Godden, R. A., Esq.—Island Phosphate from Curaçoa.

Green and Sons, Ltd., Messrs. J. G.—Sandstone from the Denwick Quarries, Alnwick.

Gregory, Messrs. J. R.—Phosphoro-calcite.

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HORSHAM URBAN DISTRICT COUNCIL.—Samples of the Strata from the boring at the Horsham Waterworks, 1903–4.

JONES, F. T., ESQ.—A series of minerals from Alderley, Cheshire.

KENDALL, PROF. P. F., M.Sc., F.G.S.—Sandstone intrusion in coal, 'rock-rolls'; contorted sandstone from a true 'wash-out' in the coal; sandstone 'drop' from the roof into the coal-seam.

KENNY, W. H., ESQ.—African Minerals.

LECKHAMPTON QUARRIES CO., LTD.—Samples of limestone, 'Cotswold Dale' Stone.

MARSHALL, F., ESQ.—Quartz coated with nail-head pyrites, Cornwall.

PRESTEA BLOCK A., LTD.—Gold-bearing quartz from the Gold Coast.

RENWICK, R., ESQ.—(*See* Horsham Urban District Council.)

ROGERS, DR. A. W.—A collection of Asbestos minerals from South Africa.

RUSSELL, ARTHUR, ESQ.—Copper-ores from Alderley Edge. Niccolite from Kirkcudbrightshire.

RUSSELL, F., ESQ., F.G.S.—A cast of a large *Bellerophon* from the dolomitic Carboniferous Limestone of Breedon Cloud.

RYLAND, F. J., ESQ.—Barytes from the Barlocco Mine, Auchencairn, Dalbeattie, and from the Potts Ghyll Mines, Cumberland.

SANDISON, REV. R. C.—Three specimens from the Chromite Quarries, Balta Sound, Unst, Shetland.

SKINNINGROVE IRON CO., LTD.—Artificial apatite.

TAYLOR, CAPTAIN W.—Scheelite and wolfram with mispickel, East Pool Mine, Cornwall.

TRUEMAN, DR. A. E., F.G.S.—Specimen of dark micaceous shale with lamellibranchs, from the *Oistoceras* sub-zone (top of Lower Lias) of Bracebridge, south of Lincoln.

VARCOE, R. W., ESQ.—China-stone with tourmaline, Cornwall.

WALEY, F. R., ESQ.—Several small specimens of ancient marbles; specimens of sal ammoniac, ruby, emerald, oil-shales, etc.

WALFORD, E. A., ESQ., F.G.S.—A *Rhynchonella* from the Great Oolite of Aynho.

WORTH, R. H., ESQ., F.G.S.—Montmorillonite from near Meldon, Devon.

ZAFFERE, P., ESQ.—Gold Ore, Alpes Mine, Southern Rhodesia.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

Six-inch reference Maps.

The following 35 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference:—

Cumberland, 48 N.W., N.E., S.W., S.E.

Kent, 2 S.W., S.E.; 8 N.W., N.E., S.E.; 9 S.W.

London, 1 S.E.; 10 S.W.; 11 S.W., S.E.

Pembrokeshire, 38 N.E., S.E.; 39 N.W., N.E., S.W., S.E.; 40 N.W., N.E. S.W., S.E.; 41 S.W., S.E.; 42 N.W., N.E., S.W., S.E.; 43 N.W., N.E. S.W.; 44 N.W., N.E.

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II.—Memoirs:

Published Memoirs.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1918, 70 pp.; 3 text figures. Price 2*s.* 6*d.* net.

Special Reports on the Mineral Resources of Great Britain:—

Vol. VIII.—Iron Ores: Hæmatites of West Cumberland, Lancashire, and the Lake District. By Bernard Smith, M.A., 182 pp., 4 plates; 29 text-figures. Price 9*s.* net.

Vol. IX.—Iron Ores (*contd.*): Sundry Unbedded Ores of Durham, East Cumberland, North Wales, Derbyshire, The Isle of Man, Bristol District and Somerset, Devon and Cornwall. By T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey, 87 pp.; 7 text figures. Price 3*s.* 6*d.* net.

Vol. X.—Iron Ores (*contd.*): The Hæmatites of the Forest of Dean and South Wales. By T. Franklin Sibly, D.Sc., 93 pp.; 14 text-figures. Price 4*s.* net.

The Geology of the Country around Lichfield, including the Northern Parts of the South Staffordshire and Warwickshire Coalfields. (Explanation of Sheet 154.) By G. Barrow, W. Gibson, D.Sc., T. C. Cantrill, B.Sc., E. E. L. Dixon, B.Sc., and C. H. Cunnington, B.Sc., with contributions by J. B. Hill, R.N., T. Eastwood, A.R.C.Sc., and J. Pringle, 302 pp.; 1 plate; 6 text figures. Price 9*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the office for reference:—

Inverness, 20; 155 N.W., N.E., S.W.
Kincardine, 1 N.E., S.W., S.E.; 2 S.W., S.E.; 10, 11, 15, 16; 18 N.E., S.E.; 19, 20; 22 N.E., S.E.; 23, 24; 26 N.W., N.E., S.E.
Nairn, 6.
Perth, 16 S.W.; 17.
Renfrew, 4 S.W.

The following clean copies, deposited provisionally in 1915–16 owing to the absence of officers on active service, have been checked, revised and deposited in the office for reference:—

Argyll, 10, 11, 19; 30 N.W., S.W., S.E.; 31, 32; 43 N.W., N.E., S.E.; 45, 46, 57, 59, 60.

Inverness, 150 N.E., S.W., S.E.; 151, 152, 159 S.E.; 160, 161, 162, 165 N.E.; 166, 167 N.W., N.E.; 168 N.W., N.E., S.E.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following six-inch clean copies (Old Series Maps), and these are now completed and deposited in the office for reference:—

Kirkcudbright, 28 N.W., N.E., S.E.; 29.

Wigtown, 5, 6, 7, 8 N.W., S.W., S.E.; 9, 10, 11, 12, 13, 14 S.W.; 15, 16, 17, 18, 19, 20, 21 N.W., N.E., S.E.; 22, 23 N.W., N.E., S.E.; 24, 25, 26, 27, 28 N.E.; 29, 30, 31 N.W., N.E., S.E.; 32 N.W., S.W.; 33 N.W., N.E., S.E.; 34; 35 N.W., S.W.; 36 N.W., S.W., 36a N.W.; 37 N.W., N.E.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1918. *See* above.

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APPENDIX I.

On a boring for Coal at Brayton Domain Colliery, Cumberland.

By Bernard Smith, M.A.

Brayton Domain Colliery is situated about 2 miles N.E. of Aspatria. The Coal Measures are reached by sinking through St. Bees Sandstone, which forms the northern limit of the exposed coalfield. The accessibility of the concealed coalfield was discussed in the Final Report of the Royal Commission on Coal Supplies, Part IX, p. 17 (1905), and it was concluded that a fault which was supposed to introduce the St. Bees Sandstone along the whole of this margin of the coalfield, must be small, if it exists, at Brayton and east of it. The explorations described in the following pages provide no evidence of such a fault. On the contrary they show that the St. Bees Sandstone is of trifling thickness near the margin, but increases rapidly northwards. A more serious obstacle to reaching the coal, however, lies in the increasing thickness of barren red measures in that direction.

At No. 4 Pit, Brayton, the Yard Band Coal of the Middle Coal Measures is worked at a depth of about 552 ft., on the south-west side of a fault with a downthrow of 30 fms. south-west (Fig. 2). To the east of this fault, where the coal has been worked, the Heathfield borehole proved the top of the Yard Band Coal, 4 ft. 6 in. in thickness, at a depth of 561 ft. 8 in. from the surface; the grey productive measures being overlain by 22 ft. of boulder clay on 46 ft. 5 in. of St. Bees Sandstone, on approximately 292 ft. 5 in. of unproductive (supposed Upper) Coal Measures. A little farther east a large fault with north-eastward downthrow has been touched in the workings at 80 fms. depth.

To prove the ground beyond this fault, borehole No. 1 was put down. This passed through 100 ft. of boulder clay, 456 ft. 4 in. of St. Bees Sandstone, and 706 ft. of unproductive measures, a total of 1,262 ft. 4 in., when the boring was abandoned owing to difficulties. Borehole No. 2 was then commenced slightly north of east of No. 1. Passing through much the same sequence it entered grey productive measures at 1,384 ft. 3 in. and passed through the top of the Yard Band Coal (3 ft. 9 in.) at 1,855 ft. 11 in., the bottom of the boring being at 1,870 ft.

Farther evidence as to the lie of the Yard Band Coal in this area being required, another boring, No. 3, was decided upon. By March, 1918, this boring had reached a depth of 2,050 ft. and was still in unproductive measures, when the Geological Survey was invited to examine the cores with a view to helping in a decision whether these measures should be assigned to the Upper Coal Measures or to some other formations. We are indebted to Mr. G. H. Askew, and to Mr. Thomas Eadie, the Colliery Manager, for valuable records of other borings and workings in the vicinity.

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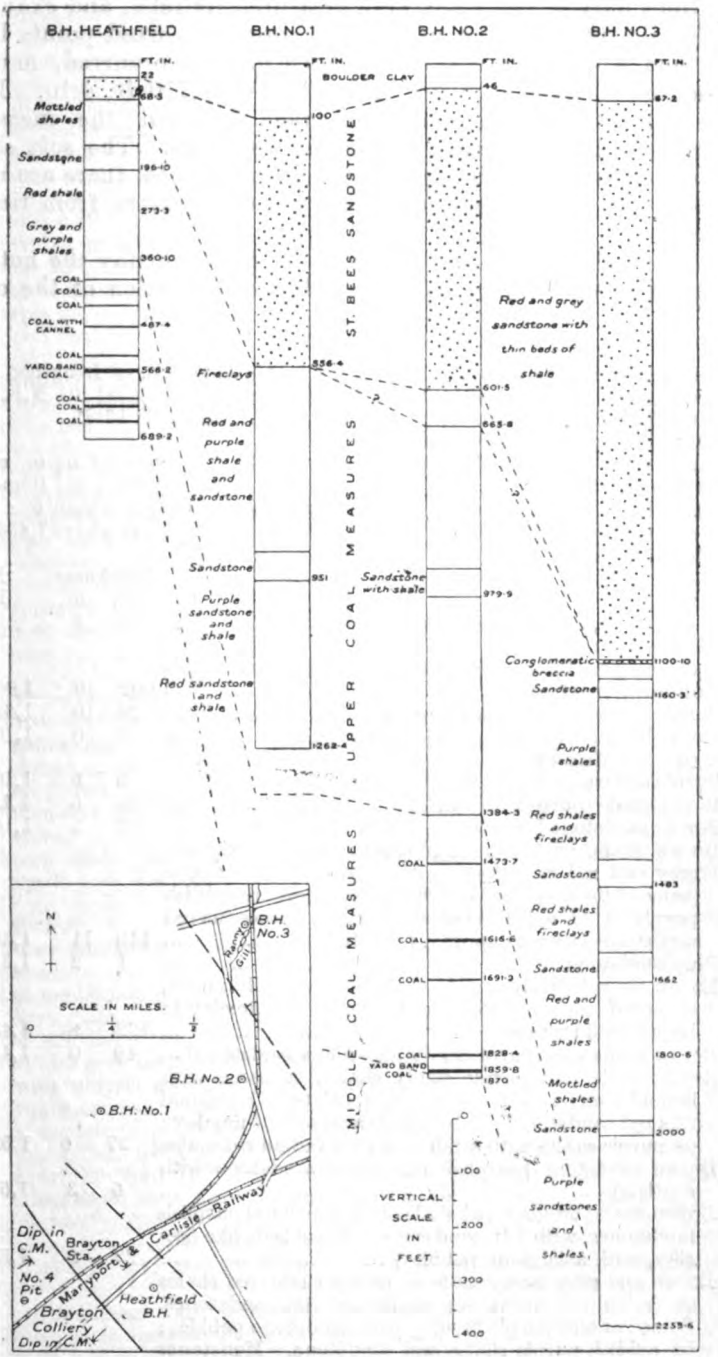
FIG. 2.—BORINGS FOR COAL AT THE BRAYTON COLLIERY, CUMBERLAND.



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Only the cores below 1,000 ft. had been kept in order, the remainder having been scattered. As no depths were marked on them, it was possible, in many cases, to give approximate positions only. The cores were measured by tape, and examined in detail, from a depth of 2,081 ft. upwards, fixed points being obtained where changes in diameter of core occurred, namely, at depths of 1,789 ft. 3 in., 1,296 ft., and 1,170 ft. 4 in. From these points adjustments were made between the measured lengths and the recorded depths of the cores. The soft shales gave trouble to the borers by caving in; hence there are many gaps in the record, and cementation was necessary from time to time.

To the following record provided by the Company the notes in square brackets have been added after examination of the cores.

Borehole No. 3 (*Fig.* 2).

This boring is situated at Ranny Gill, about ¼ mile S.E. of Langrigg. New Series one-inch Ordnance Map, Sheet 23; Old Series Geological 101 N.E. Six-inch Geological, Cumb. 28 S.W. Lat. 54° 47′5″. Long. 3° 17′8″.

Height of surface above O.D., 90 ft.

The boring, by diamond-drill, commenced 1916. Bottom of 5¼ in. core at 1,170 ft. 4 in., of 4¼ in. core at 1,296 ft., of 3¼ in. core at 1,789 ft. 3 in. Remainder 2¾ in. core. The dip in the St. Bees Sandstone is generally less than 6°; in the shales beneath it varies from 15° to 30°, and in a sandstone at about 1,434 ft., it reaches 35°.

	Thickness. Ft.	In.	Depth. Ft.	In.
GLACIAL:—				
Gravel, sand, boulders and pinnel	67	2	67	2
ST. BEES SANDSTONE:—				
Red, occasionally grey, sandstone, with numerous beds of brown [red] shale	1,002	10	1,070	0
Purple sandstone [grey at base]	26	10	1,096	10
Stone (bastard) [conglomeratic breccia]	4	0	1,100	10
UPPER COAL MEASURES:—				
Purple sandstone and shale	5	9	1,106	7
Brown shale [purple]	21	5	1,128	0
Purple sandstone [micaceous, with a little shale] ...	32	3	1,160	3
Brown shale, with a little purple and grey shale and grey and red sandstone, with gypsum veins at base [some of the above shales are purple, others are reddish purple or of a dull *brick-red* tint. A micaceous red sandstone occurs at approx. 1,210 ft.]	149	11	1,310	2
Grey sandstone	1	2	1,311	4
Brown shale [mainly purple shales, occasionally sandy, some *red*, some mottled green. Some like fireclay in beds 2 to 3 ft. thick]	122	8	1,434	0
Brown sandstone [purple shaly micaceous sandstone] ...	49	0	1,483	0
Brown shale [red purple sandy shales, on same with lamellibranchs and occasional rootlets. Occasional ribs red sandstone and beds *red* shale and of fireclay; on purple shales with sandstone; on *indian red* shales]	37	6	1,520	6
Brown sandstone [purplish micaceous sandstone with rootlets]	6	3	1,526	9
Brown shale (broken) [red shales and occasional purplish mudstones, with 1 ft. sandstone. Some beds like fireclay, with sandstone pebbles]	27	2	1,553	11
Brown and grey sandy shale on brown shale [red shales on *indian red* mudstones, shales and fine sandstones. Some *red* and purple fireclay with sandstone pebbles; on reddish-purple shales and sandstone. Mudstones and shales occasionally *bright brick-red* and fine-grained]	35	8	1,589	7

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	Thickness. Ft.	In.	Depth. Ft.	In.
Brown sandstone [reddish purple sandstone on purple micaceous sandstone with red joints]	7	6	1,597	1
Brown shale [purple shales on reddish purple fireclay (3 ft.) on variegated purple shales with pebbles and fragments of red shale]	10	1	1,607	2
Brown sandstone tinged with blue [purple]	5	7	1,612	9
Reddish-grey sandstone [grey-purple and micaceous] ...	49	3	1,662	0
Brown and grey shale (3 ft. 10 in.) on grey-blue and brown shale [purple shales, occasionally sandy, on grey or mauve shales with fragments hæmatite and red shale. Occasional beds like fireclay, with rootlets]	24	1	1,686	1
Brown sandy sandstone [purple, brown and *salmon* shales, occasionally purple; dip about 30°]	76	5	1,762	6
Brown shale (a little sandstone at 1793–4 ft.) [purple and reddish-purple micaceous shales and mudstones; dip 20°]	38	0	1,800	6
Grey sandstone [purple]	0	8	1,801	2
Purple shale [red mudstone]	2	5	1,803	7
Brown shale [red and purple mudstones, mottled green near base]	24	9	1,828	4
Brown shale [purple and *red* mudstones, some mottled]...	5	4	1,833	8
Brown sandy shale [purple micaceous shaly sandstone]	9	8	1,843	4
Brown shale [purple shales, some sandy and micaceous and slickensided]	12	3	1,855	7
Grey flint (very hard) [grey quartzitic sandstone] ...	0	7	1,856	2
Brown shale [purple mudstones (3 ft.) on *indian-red* mudstones and shales, occasionally purplish amd micaceous]	32	3	1,888	5
Brown shale tinged with blue [purplish, sandy and micaceous, mottled green]	9	2	1,897	7
Brown shale [reddish purple, sandy and micaceous, with gypsum]	5	0	1,902	7
Brown shale (broken) [purplish and sandy; slickensided]	15	8	1,918	3
Brown shale [purple and sandy, gypsum in joints; dip 35°]	3	10	1,922	1
Dark grey sandstone [purple-red siliceous sandstone] ...	7	4	1,929	5
Brown shale [mottled purple mudstones, and purple-red sandstone with gypsum, on red-purple mottled mudstones, on blue-purple ditto]	23	1	1,952	6
Hard brown stone [siliceous sandstone]	0	3	1,952	9
Brown and grey shale [purplish-red mudstones, mottled green]	18	0	1,970	9
Brown shale [sandstone, 30 ft., some speckled; on marls and shales]	60	7	2,031	4
Brown shale with a little grey shale [reddish-purple shales]	8	5	2,039	9
Brown sandstone mixed with grey [mottled mudstone, etc.]	25	6	2,065	3
Red sandstone [purplish]	1	1	2,066	4
Brown shale [„]	1	0	2,067	4
Red sandstone [„]	2	9	2,070	1
Red and grey sandstone full of mica [purplish-red shale with greyish sandstone bands, very micaceous and ripple-marked. Some purplish sandstone; dip 20°]	8	3	2,078	4
Red sandstone mixed with grey [medium grained purple, micaceous, felspathic false-bedded sandstone, layers nearly horizontal]	15	2	2,093	6
Total depth bored April 14, 1919, *was* 2,086 *ft.*				
Blue sandy shale	1	3	2,094	9
Red sandstone mixed with grey	2	9	2,097	6
Brown shale and grey sandstone	63	8	2,161	2
Grey shale	0	4	2,161	6
Grey sandstone and brown shale	1	9	2,163	3
Brown shale and sandstone	16	4	2,179	7
Brown and grey shale with mica	3	11	2,183	6
Brown sandstone with mica	3	0	2,186	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
MIDDLE COAL MEASURES ? :—				
Brown and blue shale	10	9	2,197	3
Grey sandstone	0	4	2,197	7
Brown and grey sandy shale [red and greyish-purple micaceous sandstone and shale; dip of shales, 15°] ...	20	5	2,218	0
Blue brown shale	10	3	2,228	3
Grey brown shale	3	7	2,231	10
Blue and grey shale	3	0	2,234	10
Brown and blue shale	1	0	2,235	10
[Not reported]	1	8	2,237	6

Total depth bored, measured by rods, Feb. 11, 1920, *was* 2,253 ft. 6 in.

Boring was stopped at this point and the hole cemented up, as a great quantity of dirt was dropping to the bottom.

In the above record the base of the St. Bees Sandstone has been placed at the bottom of a 4 ft. bed of conglomeratic breccia; the immediately overlying purple and grey sandstones being, apart from colour, similar in character to the red and grey sandstones of higher horizons. There being a difference in the level of this base of about 500 ft. between this boring and B.H. No. 2, it is clear that a post-Triassic fault of considerable throw intervenes.

The conglomerate consists mainly of rounded and subangular fragments set in a grit with a dolomitic matrix. The larger fragments include pebbles of marl (some ironstained), dolomite, dolomitic marl and silty marl. Some of the marly fragments appear to contain organic structures. The grit includes round and angular grains of clastic quartz, grains of silty marl, occasional felspars with albite twinning, crushed quartzite and mica.

With regard to the beds below the breccia, few of the shales are brown; the majority are of purple hue, occasionally bluish-purple, but more usually reddish-purple. Red mudstones and shales occur at intervals down to nearly 1,900 ft. Some of them are chocolate-red, when dry; others bright brick-red, when wet. Their occurrence suggests that the colouring of part at least of the series is original, and not due to secondary staining. Purplish mudstones or clays, traversed by rootlets and resembling fireclays, both in appearance and mode of weathering, occur at several horizons, but are rarely more than 3 ft. in thickness. They contain pebbles of sandstone and marl of irregular shapes.

At lower levels the mottled shales or mudstones are distinctive. They frequently present an appearance of being brecciated, and contain small pebbles of marl, sandstone, and occasionally hæmatite. A specimen from approximately 2,048 ft. was sliced, and proved to be a patchy mudstone, of which the paler portions are sericitic paste rock with some chlorite, whilst the darker portions are ironstained. The brecciated appearance in a hand-specimen is due chiefly to the unequal segregation of iron-oxide. There were a few quartz-grains and a little carbonate material.

The sandy beds are of a purplish tint as a rule, although some are reddish, whilst the more siliceous members vary from greyish-

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purple to grey. The speckled purplish-red sandstone at about 2,020 ft. is a distinctive type, which might be recognised in neighbouring boreholes. The specks are possibly due to iron; they do not appear to be manganese.

The occurrence of bluish shales in the lower 50 ft. of the record suggests that the productive Middle Measures may possibly have been entered.

In conclusion, the lithological types are similar to those found in neighbouring boreholes, and to those attributed to the Upper Coal Measures in the Midland Coalfields. They also compare closely with the Red Sandstone Group or Upper Coal Measures of the Canonbie Coalfield[1], as shown in the records of the Roanburn and Forge borings.

The lamellibranchs occurring between 1,483 and 1,520 ft. 6 in. are poorly preserved, and have been identified by Mr. J. Pringle as *Anthracomya?* They are closely similar to certain ill-preserved shells referred to *Anthracomya* found in the Keele Beds at Thurgarton (1,037 ft.) by Dr. W. Gibson[2], and at Farnsfield (855 ft.) by Prof. H. H. Swinnerton[3]. They also occur commonly in the Newcastle Beds.

There seems to be little doubt, therefore, that these beds are in the main of Upper Coal Measure Age, and form part of the Whitehaven Sandstone Series, as argued by Mr. J. D. Kendall[4].

The following points arise for discussion:—

1. Is the Whitehaven Sandstone Series unconformable to the Productive Measures?
2. What is the significance of the northward thickening of that series beneath the New Red Sandstone?

1. The colours of these beds appear to be, in the main, original. Their base, as pointed out by Kendall, is difficult to detect, because they are of similar lithological types to the Middle Coal Measures, and subject to rapid variations. The colour is no guide, for the purplish or reddish tint may or may not extend to the base at all points, and may in some cases occur even in the higher parts of the productive measures, as at Buckley in Flintshire, and to a small extent also in the Warwickshire Coalfield; or even at lower horizons, as in the case of a group of 189 ft. of red sandstones and shales that occurs nearly 1,000 ft. down in the grey measures at Wallingwells (Firbeck Colliery) on the borders of Yorkshire and Nottinghamshire, and generally between Rotherham and Retford. The 'Rotherham Red Rock,' again, with which the Whitehaven Sandstone has been compared, is now considered to include one or more rocks[5], not necessarily at the same horizon, in the Middle Coal Measures.

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[1] *Trans. Royal Soc., Edinburgh*, vol. xl, pt. iv (No. 32), 1903, pp. 858–865, and 'Summary of Progress' (*Mem. Geol. Surv.*) for 1902, 1903, pp. 214–6.

[2] Unpublished.

[3] Unpublished, but specimens preserved in the Palæontological Department of the Geological Survey.

[4] 'The Whitehaven Sandstone Series,' *Trans. Fed. Inst. Min. Eng.*, vol. x, 1895–96, pp. 202–224.

[5] Prof. P. F. Kendall, *Final Rep. Roy. Com. on Coal Supplies*, part ix, Appendix iii, 1905, p. 22.

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J. D. Kendall maintains that there is a considerable unconformity between the two groups. His conclusion is based partly upon lithology and colour, but largely upon the varying thickness between the Yard Band Coal and the supposed base of the Whitehaven Sandstone Series at different points, and also on the supposed persistence of two coal-seams near the base of the Whitehaven Sandstone Series in the northern area.

The fact remains, however, that the base of the series cannot at present be fixed either by fossil evidence or by lithological character, and the absence of certain coals, near the top of the Middle Coal Measures, is at best negative evidence, and may be due to impersistence.

Newell Arber[1] claimed that the lower 200 ft. at least of the Whitehaven Sandstone Series was of Middle Coal Measure age, and that the unconformity, if present, between the Sandstone Series and the Productive Measures does not mark any considerable interval in geological time.

The Whitehaven Sandstone Series proved in the Brayton No. 3 borehole consists largely of shales, the proportion of shale to sandstone being roughly as 75:25, figures that agree with Kendall's estimate of the proportions in the series in this area.

2. At Frizington Hall, near Whitehaven, 531 ft. of Whitehaven Sandstone has been proved by boring[2]. The top had been denuded, but Arber estimated the full original thickness to have been at least 600 ft. At Brayton No. 3 boring a vertical depth of over 1,000 ft. of these rocks has already been penetrated, representing a true thickness of about 900 ft.

The Brayton boreholes show an increase in thickness (measured vertically) in a northerly direction of about 800 ft. in a little over one mile. Dips measured on the cores of No. 3 give an average difference of about 15° between the dip of the St. Bees Sandstone and that of the underlying strata. If we assume that these Carboniferous Rocks were dipping northwards towards the centre of the Carlisle Basin before the deposition of the New Red Sandstone and the occurrence of later faulting, a dip of this amount over a horizontal distance of a mile would give an increased (vertical) thickness of about 1,420 ft. Hence the difference in dip provides a sufficient explanation of the increase in thickness (without considering possible movements at different dates along fault-lines), even if we take it that the direction of dip of the beds was rather north-north-westward than true north.

The conclusion seems to follow that should the above rate of thickening continue northward, together with an increasing depth of Triassic cover, the productive Middle Coal Measures will be carried down rapidly to depths at which they cannot be reached and worked with profit.

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[1] 'The Fossil Flora of the Cumberland Coalfield, and the Palæobotanical Evidence with regard to the Age of the Beds,' *Quart. Journ. Geol. Soc.*, vol. lix, 1903, pp. 1–22.

[2] 'The Whitehaven Sandstone Series,' *Trans. Fed. Inst. Min. Eng.*, vol. x, 1895–6, pp. 215–216.

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APPENDIX II.

On the North-Western corner of the Lothian Oil-shale Field.

By G. W. Lee, D.Sc.

The north-western corner of the Scottish Oil-shale Field, consisting of an area of some two or three square miles around Blackness village (Six-inch Sheet, Linlithgow, 2 S.W.), has long been of interest to all connected with the oil-shale industry. Little was known of the district, as testified by the fact that the existing geological maps do not carry the lines of crop of the workable shale seams much further west than Philpstoun, but the simple structure of the ground, the geologically high position of the strata, and the continuity of the district with the valuable Philpstoun shale-field, were regarded as offering distinct possibilities of untapped resources[1]. Recent boring operations were therefore closely followed by the Geological Survey. The results were unsatisfactory from the mining point of view, but of considerable geological interest, and we have to express our indebtedness to Mr. J. Kidd, M.P., for his permission to make use of the information obtained.

No. 1 bore was put down on the west bank of the Black Burn, $\frac{1}{8}$ mile S.E. of Blackness, and No. 2 bore in a little quarry on the shore, 500 yards west of Blackness. As there is on the whole an ascending sequence from east to west, the second bore starts in a newer stratum than the first, and as it was carried down to the same horizon it offers the fuller sequence.

The following is condensed from the borer's log:—

	Thickness.			Depth.		
	Fm.	ft.	in.	Fm.	ft.	in.
Rubbish, blaes[2] and balls	–	–	–	3	3	0
Dark-grey limestone	0	1	6	3	4	6
Strata (mostly blaes)	4	–	–	6	1	9
Oil-shale	0	0	4	6	2	1
Sandstone	–	–	–	–	–	–
Limestone, brown earthy	0	0	3	6	3	9
Strata (mostly fakes and sandstone)	–	–	–	11	4	9
Blaes	–	–	–	16	4	6
Sandstone, fakes, blaes and ironstone	–	–	–	37	0	6
Black blaes	3	2	7	40	3	1
Dark-grey shale with fossils	0	5	0	41	2	1
Strata, mostly blaes with four beds of sandstone and a teschenite-sill 160 ft. thick	–	–	–	97	0	0
Shaly blaes and grey blaes	1	3	6	98	3	6
Dark-grey blaes with limy ribs and balls	2	2	2	100	5	8

[1] 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., p. 65.

[2] For explanation of terms used by Scottish borers, *see* p. 34, footnote.

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	Thickness. Fm.	ft.	in.	Depth. Fm.	ft.	in.
Strata (mostly blaes and fakes)	–	–	–	109	3	8
Ash	1	3	1	111	0	9
Strata	–	–	–	112	3	10
Ash	0	4	2	113	2	0
Blaes	–	–	–	120	5	1
Limestone and ironstone	0	0	6	120	5	7
Shaly blaes	0	1	4	121	0	11
Fakes	0	1	4	121	2	3
Coal	0	1	2	121	3	5
Marl	7	3	11	129	1	4
Fakes and fireclay	–	–	–	130	2	8
Coal plies	0	0	1	130	2	9
Fireclay, fakes, blaes	–	–	–	139	1	0
Coal	0	0	3	139	1	3
Fakes	–	–	–	141	1	0
Sandstone	5	5	6	147	0	6
Fakes and sandstone and faky blaes	–	–	–	154	3	6
Blaes	0	3	6	155	1	0
Limestone	3	3	11	158	4	11
Greenish marl	0	0	5	158	5	4
Strata, mostly burnt blaes	1	2	10	160	2	2
Coaly blaes, burnt	0	1	9	160	3	11
White whin and burnt blaes	–	–	–	162	2	5
Limestone	1	2	3	163	4	8
Fakes and sandstone	4	5	6	168	4	2
Sandstone	4	3	0	173	1	2
Strata, mostly fakes	–	–	–	180	5	2
Blaes with a layer of large *Estheria*	5	4	0	186	3	2
Black limestone	0	0	3	187	0	2
Sandstone, fakes and clay	2	0	0	189	0	2
Limestone	5	4	1	194	4	3

(Bore stopped in limestone.)

The limestone at the depth of 3 fathoms 4 ft. 6 in. is hard, grey, crinoidal and contains remains of *Productus*, *Lingula*, and other fossils. Its characters agree with those of the Riccarton Limestone, which lies not far below the Cobbinshaw position[1]. It is to be noted that in the West Calder district a thin crinoidal limestone has been met with 25 fms. below the Cobbinshaw ('Hurlet') Limestone and Coal.

The black blaes at 40 fms., which have been burnt by the sill lower down, are of a sufficiently fine texture to be regarded as having possibly once been of the nature of oil-shale. The blaes which underlie them are of marine origin and contain remains of goniatites. It is a significant fact that goniatites have been found below the Fraser Shale position in the West Calder district, and that the distance between that shale and the crinoidal limestone is there almost the same as in the Blackness boring, viz.—about 40 fms. The inference is that this burnt blaes represents the Fraser Shale. The next stratum of interest is the "shaly"

[1] 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 65.

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blaes, or poor oil-shale at 98 fms. A marine fossiliferous bed underlies it, in which goniatites and the lamellibranch *Posidonomya becheri* are conspicuous. These fossils, again, are known from under the Raeburn Shale. That this 'shale' is the Raeburn is all the more probable when its position is considered relatively to that of the bed taken to be in the Fraser Shale position, and to that of the Two-Foot Coal—the next recognisable index: in both cases after deduction of the sill the distances agree well with the distances between these seams in the West Calder district. The position of the Two Foot Coal is clearly represented by the impure coal at 121 fms., and the Houston Marl is developed with the usual characters. The above remarks show that in the Blackness district the strata between the base of the Carboniferous Limestone and the base of the Houston Marl possess the development and aspect of the equivalent strata in the typical oil-shale districts, the only difference being in the quality of the shales, which here have no economic value. On the other hand, from the Houston Marl downwards to the Burdiehouse Limestone there is a sudden and remarkable departure from the normal.

It ought to be stated that the cores of the borings were carefully examined by a skilled borer, and at frequent intervals by the writer for the purposes of this report, with special reference to any possibility of faulting. No trace of faulting was detected anywhere below the Houston Marl. The Houston Coal and Grey Shale, poorly represented in No. 1 Bore, have almost disappeared in No. 2 Bore. The Fells Shale is totally absent, arenaceous sediments taking its place. The Broxburn Marls have disappeared except for a layer 5 in. thick of greenish colour and of the usual soapy texture; and, on the other hand, there is an exaggerated development of the "cement" bands usually found in the Marls: here they form thick limestones which occupy the larger part of the series. The Broxburn Shale is recognisable in No. 1 Bore and is 10 ft. thick. The oil-content is only 9 gallons per ton, but the oil is of high quality. The sulphate of ammonia amounts to 40 lbs. per ton. In No. 2 Bore the position is occupied by blaes, burnt by a small sill. In the first bore the Broxburn position is 35 fms. below the base of the Houston Marls, and only 30 fms. in the second bore.

The strata between the Broxburn position and the Burdiehouse Limestone show extreme attenuation, the distance being 49 fms. in No. 1 Bore, and only 29 fms. in No. 2 Bore, against over 100 fms. in the Philpstoun field. The solid sandstone some 10 fms. below the Broxburn position may be taken to be the Binney Sandstone, but there is no trace of the Dunnet Shale, nor is there room for the thick set of strata which normally would come below.

In No. 1 Bore a poor oil-shale 14 ft. thick rests on the top bed of the Burdiehouse Limestone, and would thus represent the Camps Shale. It underlies a light-brown entomostracan limestone about 12 ft. thick, which may possibly take the place of cement-ribs met with about that position in the Philpstoun field. In No. 2 Bore the poor oil-shale is replaced by black blaes, and the overlying limestone is absent.

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The Burdiehouse Limestone is of the usual type and of considerable thickness. In No. 1 Bore 3 fms. of blaes separate a top bed 42 ft. 6 in. thick from a lower bed in which the boring stopped.

To sum up, these two borings indicate, firstly, that the Blackness district does not contain reserves of oil-shale; secondly, that the sequence above the Houston Coal position is fully developed; and, thirdly, that the sequence between the Houston Coal and the Burdiehouse Limestone shows intense attenuation.

These points are brought out in the sections forming Fig. 3, two of which, namely, that of West Calder and that of Bridgend, are borrowed from the Geological Survey Memoir.

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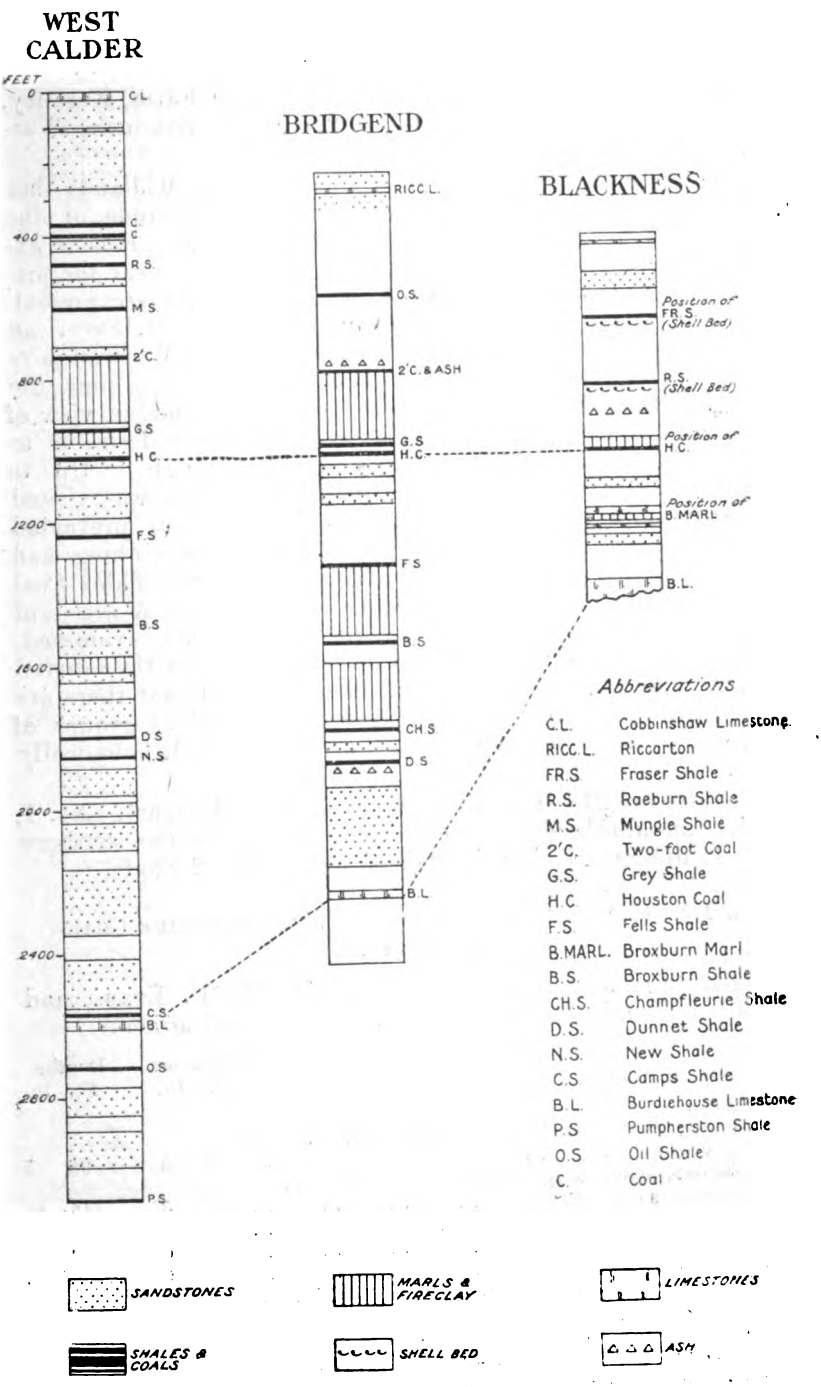
FIG. 3.—COMPARATIVE VERTICAL SECTIONS, SHOWING ATTENUATION OF THICKNESSES IN THE NORTH-WESTERN CORNER OF THE LOTHIAN OIL-SHALE FIELD.



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APPENDIX III.

Coventry Colliery.

By T. Eastwood.

The colliery is situated near Newland House Farm, Keresley, in the New Series One-inch Map 169, and the Six-inch, Warwick, 16 S.E.

There seems to be a widespread notion in the Midlands that workable coals terminate southwards on the latitude of the southern end of the South Staffordshire Coalfield. Recent explorations in Warwickshire prove that, at any rate near the prescribed boundary, workable seams of good quality are present. In the 'Summary of Progress for 1914' (*Mem. Geol. Surv.*) an account is given of two borings put down by the Warwickshire Coal Co., at Keresley and Whitmore Park. Since then the colliery shafts at Keresley have been completed, and, in view of possible future explorations to the south, it seems desirable to publish a description of the strata passed through. Up to November, 1915, the sinking to a depth of 730 ft. was visited periodically and the material examined. The war prevented further investigation until February, 1919, when sinking had been finished and roads had been driven out in the Thick Coal to two or three hundred yards from the shafts. A series of specimens that had been kept at the colliery were examined. These were not quite complete and of small size, but they served to identify the main sub-divisions. They showed that there are no sharp lines of demarcation between the various groups of strata, and that the Keele and the Corley beds are lithologically similar.

The shafts are 21½ ft. in diameter and 60 yards apart. No. 1, of which an abridged section is given below, is the southern shaft. It differs only in minor details from No. 2 Shaft.

No. 1 Shaft, Coventry colliery, Warwickshire Coal Company.

(Abridged from a section supplied by Mr. W. P. Evans, and notes in square brackets added to the original account.)

	Thickness. Ft.	In.	Depth. Ft.	In.
Upper Coal Measures:—				
Corley Beds—				
Red marls, sandy in part with occasional thin red and grey sandstones	98	5	98	5
Red sandstone and conglomerate [pellets of marl in a calcareous sandy matrix]	47	5	145	10
Red marls with thin sandstone bands	11	8	157	6
Hard red sandstone	20	6	178	0
Red marl	143	6	321	6
Red sandstone [purplish coarse sandstone with scattered pebbles] and conglomerate [dark-purplish sandstone-pebbles of Silurian age, and red and yellow cherts and white-grey limestone of Carboniferous age. Arley Exhall Conglomerate]	116	6	438	0

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	Thickness. Ft.	In.	Depth. Ft.	In.
Keele Beds—				
Red marl and red and grey marl	55	8	493	8
Red and grey sandstone very jointy; pebbly in lower part [pellet bed]	25	1	518	9
Red sandstones with thin marls	209	9	728	6
Alternating beds of red marl and sandy marl ...	57	0	785	6
Grey sandstone [? *Spirorbis Limestone* of Longford Tileries]...	1	0	786	6
Alternate red marls, sandy marls and sandstones ...	146	0	932	6
Red and blue marls, sandy marls and sandstones; a little grey conglomerate at base with coal streaks, *Stigmaria and Sigillaria*	270	9	1,203	3
Halesowen Series—				
Brown and blue marl	46	9	1,250	0
Blue marly conglomerate 3 ft. 9 in. blue limy sandstone 3 ft.; green blue limestone 2 ft. 9 in. [fine calcareous sandstone] blue limy sandstone 1 ft.	10	6	1,260	6
Brown and blue marls and shales	81	6	1,342	0
Bastard blue limestone with ironstone balls [fine calcareous sandstone [? Index Limestone]	3	6	1,345	6
Blue and brown marls and blue shales	93	6	1,439	0
Coal	0	10	1,439	10
Dark-blue shale with a little fireclay	23	8	1,463	6
Blue sandstone	56	6	1,520	0
Coal	0	4	1,520	4
Blue sandy shale with limestone-balls	43	8	1,564	0
Grey rock, flaggy in lower part	35	9	1,599	9
Coal, irregular contorted band	0	3	1,600	0
Dark fireclay and blue shales with ironstone-balls ...	19	0	1,619	0
Coal	1	0	1,620	0
Dark fireclay and blue shales with ironstone-balls ...	6	6	1,626	6
Coal and bass	0	6	1,627	0
Etruria Marls—				
Blue sandy fireclay and shale	11	0	1,638	0
Purple and yellow marl	7	0	1,645	0
Blue sandy shale 27 ft. 6 in., brown marl 1 ft. 3 in.; fine-grained blue sandstone 16 ft. 3 in., multicoloured sandy shale 1 ft. 9 in....	46	9	1,691	9
Blue sandstone with irregular bands and pockets of brown-grey conglomerate [Espley Rock] and brown and blue sandy shale	33	9	1,725	6
Blue, brown and yellow marl	22	0	1,747	6
Grey rock [Espley Rock] with shale and fireclay nodules	16	6	1,764	0
Yellow and brown fireclay and grey sandy shale ...	17	0	1,781	0
Middle Coal Measures:—				
Grey rock	47	0	1,828	0
Grey fireclays and shales with some ironstone ...	95	0	1,923	0
Coal	1	6	1,924	6
Grey shaly sandstone	45	0	1,969	6
Coal 2 ft. 5 in.; coal and dirt 9 in.; coal 1 ft. 9 in. [Four Feet Coal]	4	11	1,974	5
Grey sandy fireclays and shales with ironstone-balls [4 ft. 6 in. of black shale at 2,014 ft. may represent the ? "Marine horizon" of the boreholes]	118	3	2,092	8
Blue shale with ironstone-bands—"Ragged Stone" Ironstone Measures	18	9	2,111	5
Black shale	1	9	2,113	2
Thick Coal: Coal—Two Yard Coal	5	4		
Holing dirt	0	4		
Coal—Ryder and Ell Coals [no visible parting] ...	9	11		
Holing dirt	0	1		
Coal—Slate Coal	6	0	2,134	10

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	Thickness. Ft.	In.	Depth. Ft.	In.
Holing dirt	1	2	2,136	0
Coal—Lady Coal	1	8	2,137	8
Dark fireclay and grey sandy shales with ironstone-balls [White Ironstone Measures]	26	10	2,164	6
Coal—Seven Feet Coal	3	4	2,167	10
Brown and grey fireclay with ironstone-balls... ...	4	2	2,172	0

The belt of sandstones and conglomerate at 438 ft. may be matched perfectly with the exposures at Arley station, and at Exhall. Here, as elsewhere, they form a convenient base to the Corley Beds, though the rocks above and below them are of similar aspect.

In the Keele Beds the nodular Spirorbis limestone (probably equivalent to that of Maxstoke) found near the top of the series in the two borings was not recognised in the shafts, but the "grey sandstone" 1 ft. thick at a depth of 786 ft. in No. 1 probably represents the Spirorbis limestone that occurs about 400 ft. above the base of the Keele Beds at the brickpit by Longford station. It will be noticed that there is a greater development of sandstone above this horizon at the shafts than in the borings.

The Etruria Marls maintain the same thickness as near Nuneaton, but are mainly grey in colour, though a few thin beds of typical purple and mottled marls are present in addition to Espley Rocks.

The measures between the base of the Etruria Marls and the Thick Coal call for little remark.

The Thick Coal is said to be of good quality. The "Spires" (a rather dull compact coal of good quality) of the Ell seam are present as usual, and in places the Slate Coal takes on in part a "spiry" character with a small development of bastard cannel. The Ell and Ryder together vary from 10 to 11 ft. in thickness. The inferior coal known as the Bare Seam, which elsewhere occurs between the Two Yard and Ryder coals, appears to be absent, but the pea-like "Ryder stone" occurs in thin lenticles near the base of the upper seam.

Near the shaft the seam suffers from slight rolls, and is split in places by irregular partings of hard white micaceous sandstone a few inches in thickness, which have the appearance at first sight of intrusive white trap.

Water from fissures proved a serious obstacle to sinking. Down to 180 ft. the flow amounted to 500 gallons per minute. This was shut off by coffering. The sandstones and conglomerates at the base of the Corley beds yielded 2,600 gallons per minute in both shafts, and were shut off by cast-iron tubbing. On resuming sinking, water again proved troublesome, and the cementation-process for stopping the fissures was adopted with great success.

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APPENDIX IV.

Note on the Lower Greensand in the West Bilney Borehole, Norfolk.

By J. Pringle.

This borehole, made in 1918, is situated 4/5 of a mile south of West Bilney, about six miles south-east of Kings Lynn. It commenced in superficial deposits at an estimated height of about 20 ft. above O.D., and, after passing through the Lower Greensand, entered Kimmeridge Clay at the depth of 130½ ft. In a brief account of the latter formation published elsewhere,[1] the details of the Lower Greensand were not set forth: these are as follows:—

	Thickness. ft.	in.	Depth. ft.	in.
Superficial deposits	19	6	19	6
Light-brown and silvery sands	74	0	–	–
Blue sandy clay, not examined	0	6	–	–
Hard glauconitic sandstone with small brown phosphatic pebbles	0	4	–	–
Soft incoherent glauconitic sand	2	0	–	–
Brownish-green glauconitic sandstone with fragments of lignite	0	10	–	–
Dark-brown fine-grained glauconitic sand with small patches of white sand	5	0	–	–
Hard dark-brown glauconitic grit with irregular fragments of compact fine-grained brown sandstone ..	0	6	–	–
Soft dark-grey glauconitic sand with fragments of lignite	21	10	–	–
Grey sandy limestone with numerous small well-rounded black phosphatic nodules, some enclosing shell-fragments. Iron pyrites plentiful in matrix ...	2	0	–	–
Dark-brown fine-grained glauconitic sand	4	0	130	6
Kimmeridge Clay	153	8	284	2

The uppermost part of the section is based on the cores obtained from a second borehole situated a few feet away from the earlier hole. It is likely that the whole of the sands belong to the Sandringham Sands, which are said to be probably over 100 ft. thick.[2] There was no sign of the Snettisham Clay. According to the bore-record a hard grey sandy limestone, full of well-rounded black phosphatic nodules, was passed through 4 ft. above the base of the formation. This limestone is evidently a basement-bed, and its position as recorded may be due to an accidental reversal of the cores before the journal was made.

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[1] 'Special Reports on the Mineral Resources of Great Britain,' *Mem. Geol. Surv.*, vol. vii, 2nd ed. (in the press), p. 37.

[2] 'The Geology of the Borders of the Wash,' *Mem. Geol. Surv.*, 1899, p. 5.

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APPENDIX V.

Glauconite-sand in Borings near Lewes, Sussex.

By Sir A. Strahan, K.B.E., etc.

A boring, recently been made by Messrs. Duke and Ockenden at Iford, near Lewes, started in alluvium, and after passing through a few feet of Lower Chalk, penetrated the Upper Greensand and Gault, the section as supplied by the borer being as follows:—

	Thickness. Ft.	Depth. Ft.
Marl and gravel	25	25
Rock and clay	11	36
Clay	289	325
Black sand	5	330
Sand	4	334

Water overflows at 180 gallons per hour. Rest level 21 ft. above surface. The height of the surface is about 30 or 35 ft. O.D.

The "black sand" at 330 ft. depth consists almost wholly (upwards of 99 per cent.) of grains of glauconite. The grains are of rounded or subangular outline, averaging 0·2 mm. in diameter and are loosely held together. This glauconite-sand, which appears to be unique in Britain, is being made the subject of further examination. It differs from the glauconitic rock of Ebbsfleet, described in the 'Summary of Progress' for 1911, pp. 72, 73, in the respect that the glauconite in that rock formed a cementing matrix in which quartz-grains were embedded.

A boring now in progress, midway between Plumpton and Plumpton Station and 5½ miles N.W. of Iford, has reached the same glauconite-bed under 130 ft. of Gault. The rock is not conspicuously granular, but appears to be made up to the extent of about 90 per cent. of glauconite in a finely divided state, with an admixture of rounded grains of quartz and some argillaceous material. It is 4 ft. thick.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1920.

I.—INTRODUCTION.

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

During the year 1920 changes on the staff of the Geological Survey were exceptionally numerous and important. In July Sir Aubrey Strahan, Director, and Mr. G. W. Lamplugh, Assistant Director (for England and Wales), retired after completing their service; Dr. Flett (Assistant Director for Scotland) was appointed Director, and Mr. J. Allen Howe (Curator of the Museum) became Assistant Director in Mr. Lamplugh's place. Dr. Walcot Gibson was promoted Assistant Director for Scotland in succession to Dr. Flett, and proceeded to Edinburgh in November. Dr. McLintock, of the Royal Scottish Museum, formerly a member of the staff of the Museum of Practical Geology, was appointed to succeed Mr. Allen Howe as Curator, but did not take up his duties before the close of the year. The staff was expanded by the appointment of six geologists, and Mr. Henry Dewey and Mr. Bernard Smith were appointed District Geologists.

It was decided to begin the revision of the maps of some of the more important districts of the North of England, and to open local offices in Newcastle-upon-Tyne and in Whitehaven. Mr. R. G. Carruthers is to take charge of a field-unit, comprising four geologists, in the Northumberland and Durham district, and Mr. Bernard Smith is to superintend the work of a similar unit in Cumberland and Westmorland. By the close of the year a start had been made in the work of organising these new field-units.

In England and Wales during 1920 work was continued in all the districts in which mapping had been in progress before the war, viz., the London district under Mr. R. G. Carruthers, the Warwickshire and Staffordshire district under Dr. Walcot Gibson, and in Shropshire under Mr. T. C. Cantrill. At the same time it

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was necessary to continue the investigation of the country's resources of economic minerals, which had been in progress during the previous six years, in order to complete the series of Special Reports on the Mineral Resources of Great Britain, inaugurated by Sir Aubrey Strahan, which had proved so successful. Of these the principal were a series of reports on the lead and zinc ores of England and Wales, on copper ores, and on salt deposits. At the close of the year these reports had been completed in manuscript, and were in the press or being edited for publication. Several reports on iron ores, arsenic, fireclays and siliceous refractories were published during 1920, and new editions of the reports on silica rocks and on cannel coal, mineral oil, etc., in England were issued. In all these cases a certain amount of field-work had to be done to bring the information up to date.

In Scotland field-work was continued in all the districts which were in hand before the War, viz., Ayrshire, the Central coalfield (with Clackmannanshire), Mull and the adjacent islands, and Sutherlandshire, but part of the time of the staff during the summer was taken up with special enquiries. Mr. Wilson has prepared a report on the lead, zinc and copper ores of Scotland, which involved much field-work. Dr. Lee has begun a revision of the Secondary rocks of the Brora coalfield, with especial reference to the correct determination of the palæontological zones. Mr. Macgregor has edited a report on the iron ores of Scotland, which was published during the year.

In the London district Mr. Carruthers and his staff have been at work principally in the Lea Valley, and near Crayford and Erith on the south side of the Thames. Several points of interest have been added to the information available. The Reading Beds of Collier's End show great lateral variation, which may indicate that they are unconformably overlapped by the London Clay. Near Swanscombe the Blackheath Beds are exceedingly thin, and may, indeed, be absent in places; but near Shorne they have a thickness of about 20 ft., and are apparently of normal character. The terraces of the Lea Valley have been the subject of careful study.

The Swanscombe gravels, which yield many palæolithic flint implements, are divisible into a 100-ft. terrace, and the 50-ft. deposits, of which the latter apparently form a continuous series down to the bottom of the buried channel of the Thames.

In the Midlands district (Warwickshire and Staffordshire) the solid rocks surveyed are Cambrian, Silurian, Carboniferous and New Red. A small area of the quartzite of the Lickey Hills, near Rubery, enters the Birmingham Sheet, but it has not been proved to contain fossils, and is presumptively of Lower Cambrian age. Of the Silurian rocks of this district the Upper Llandovery is represented by a fossiliferous sandstone near Rubery village. The Wenlock strata which follow, especially those of the Wren's Nest, Dudley, are well known to all geologists. They comprise the Wenlock Shales and Limestone, long quarried and now

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mined. Above these the Ludlow Shales and the higher Silurian up to the horizon of the Ledbury Passage Beds have a fairly extensive development within the area surveyed during the year, especially around Turner's Hill and Ellowes Park. The Upper Carboniferous of the Dudley district comprises the Etruria Marls, the Keele Beds and the Hamstead Beds, of which the last-named contains a limestone-breccia, or calcareous conglomerate. Near Halesowen the Halesowen Sandstone contains Spirorbis limestones and three seams of coal which are not workable. The Keele Beds and Hamstead Beds, which occupy the top of the Carboniferous succession, are very typically developed, and seem to be quite conformable throughout.

The Bunter and Keuper of Newport (Salop) present some features in common, but are, on the whole, well-characterised and distinct. An unconformability probably occurs between them, but its significance is at present impossible to estimate. In the Birmingham area the Upper Mottled Sandstone assumes great importance, and has served as a source for moulding sands, which are of high reputation.

The Glacial deposits of the Midlands in the vicinity of Newport and Birmingham, though they have been very minutely investigated by many local geologists, continue to furnish results which are of great interest as a record of the closing stages of the Glacial period. Around Newport sands and gravels were deposited as series of fans, the different series marking successive positions of the ice-front. Apparently there are no terminal moraines. Eskers trending at right-angles to the ice-front connect corresponding fans in the several series. At a later stage an extensive lake covered the area up to the 300-ft. contour. Its shore-line is shown in places by terraces, but as a rule merely by a notch.

Although systematic mapping has not yet been begun in the Whitehaven district, Mr. Smith has had opportunity of examining the cores of certain bores that have recently been made. He finds that these indicate a remarkable change in the character of the Carboniferous Limestone in the vicinity of the boundary fault of the exposed Whitehaven coalfield. This was not wholly unexpected, as the surface indications had suggested a similar conclusion; but it is evident that when the mapping has demonstrated the conditions in the exposed coalfield, and further boring has taken place, important results may be anticipated.

In Scotland the field-staff were engaged during most of the summer in the primary 6-in. survey of the Highlands. New light has been thrown on the geology of Iona by Mr. Anderson, who finds that the island consists of a platform of Lewisian Gneiss overlain by Torridon sediments. In the Lewisian there are rocks of igneous, and others of sedimentary origin; among the latter are the well-known Iona marble and dark graphitic schists. Intrusive masses of epidiorite and pegmatite traverse the gneisses and schists. The basal conglomerate of the Torridon is, in

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places, intensely crushed, but the common boundary of the two series is not regarded as a thrust-plane. Dykes of basalt and lamprophyre intersect the Torridon strata, and the Newer Granite of the Ross of Mull possibly produces contact alteration in these sediments.

A very interesting section at Gribun, in the Island of Mull, has now been investigated for the first time since Professor Judd described it in 1878. Many fossils have been collected, and have been determined by Dr. Lee. Trias and Rhaetic rocks form the basement, the latter yielding characteristic fossils. Broadford Beds follow (Hettangian and Sinemurian) containing well-preserved fossils, and Cretaceous rocks, including Cenomanian (Greensand). The whole sequence is interesting as affording one of the most important exposures of Secondary rocks in the island of Mull. In Ardnamurchan Mr. Richey has found a considerable outlier which is probably Inferior Oolite though it has a resemblance to Chalk.

The mapping of Mull has been completed, and the reports describe the usual variety of lavas and basic intrusions, with additional information on the Secondary rocks that underlie the volcanic plateau, and the Tertiary sediments among the lavas. The famous fossil tree of Burgh, which has been known for over a hundred years, has been very carefully described, and specimens of the fossil wood sliced for microscopic examination. Ardnamurchan, which is part of a Tertiary volcano of the same age as the mountains of Skye and Mull, has been visited by Mr. Richey, but the actual survey of the ground has hardly been begun. Staffa, famous for its basaltic pillars and caves, consists mainly of a single lava with its slaggy top covered by a thin layer of ash. One small, intrusive sill with clearly transgressive margins occurs below the base of the lava.

In Easter Ross the area surveyed consisted mainly of typical Moine gneisses intersected by lamprophyre dykes, and in the adjacent parts of Sutherland there are also granitic intrusions with allied basic masses which occasionally give rise to rocks of hybrid origin.

The igneous rocks which form the uplands around the North Ayrshire coalfield have been shown to include an extensive development of trachytic lavas overlain by basalts of Dalmeny type. These trachyte lavas may occur in two series, and are of interest because most of the trachytes of the West of Scotland have hitherto been believed to be of intrusive origin.

In Stirlingshire Mr. Dinham has brought to light an encrinital limestone which provides an important landmark in the correlation of the Carboniferous Limestones of Campsie with those of the Bannockburn district.

The Alloa coalfield of Clackmannanshire forms a link between the Central coalfield and that of West Fife. The revision is now in hand, and it is considered open to question whether the Barren Red Measures of the Upper Carboniferous occur in this area, as has hitherto been supposed.

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Extensive mining developments are taking place in the Douglas coalfield, and much new information is being collected especially from bores in progress. The revision of this district is proving of great interest, and resulting in a much more correct interpretation of the complicated structure of this coalfield.

Dr. H. H. Thomas has made an investigation into the petrographical characters of the foreign stones that compose the inner circle at Stonehenge, and arrives at the conclusion that they have been transported by human agency from Prescelly Mountains in Pembrokeshire, no doubt expressly for the purpose. This seems to set at rest a question which has long interested the antiquarian, and sheds an interesting light on the importance in which the building of Stonehenge was held by the early races of Britain.

II.—FIELD WORK.

(A)—ENGLAND AND WALES.

1. London and South-Eastern District.

H. Dewey, District Geologist.
R. L. Sherlock, D.Sc., A.R.C.S.
C. E. N. Bromehead, B.A.
R. W. Pocock, B.Sc.
T. Robertson, B.Sc.
} Geologists.

In the London District the mapping, which was suspended during the war, has been continued in an easterly direction on both sides of the Thames. On the southern side, Mr. Bromehead has surveyed the ground in Sheet 271 (Dartford) extending from Erith and Crayford to the margin of the map a mile or two east of Gravesend.

Dr. Sherlock has mapped in Sheet 239 (Hertford) the area extending eastwards from Hertford to Ware and thence down the Lea Valley to Cheshunt, and a small area in Sheet 221 (Hitchin) between Woodhall Park and Sacombe. Mr. Pocock and Mr. Robertson were engaged for a few weeks mapping the ground around Goff's Oak, Northaw and Cheshunt. Some parts of the North London map (Sheet 256) have been revised by Mr. Bromehead, especially the districts of Hampstead, Holloway, Stoke Newington, Bow, and West Ham, while Mr. Pocock has revised those of Watford, Bushey and Stanmore. The work was under the superintendence of Mr. Carruthers until his transference to Northumberland in October, when it was placed in the charge of Mr. Dewey.

CRETACEOUS.

The Chalk bordering the Thames between Erith and Gravesend has been mapped by Mr. Bromehead. It all belongs to the zone

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of *Micraster coranguinum*, as previously ascertained by Mr. Dibley.[1]

TERTIARY.

Dr. Sherlock records a section of abnormal Reading Beds at the south of Collier's End village (Sheet 221) in a disused brickyard. Below 8 ft. of lead-grey clay with brown mottling, which appears to be London Clay, there is a sharp plane of division. In downward succession it is followed by 3 ft. of black, somewhat silty clay, mostly stoneless, but with occasional flint-pebbles, some of which stand vertically. Most of the pebbles are black but some are yellow and others red, and a few are fragmentary. The black clay is local, being absent from a pit only 200 yds. to the west. The black bed passes down quickly, but with a sharp dividing plane, into 8 ft. of greenish-grey, sandy clay with indefinite crimson patches, which contains a few calcareous nodules. Below the clay is a stony mass of flints and flint pebbles resting on a piped surface of chalk, with the usual black or green-coated flints at the junction. Less than a mile to the east there is a 12-ft. pit in the typical fine white sand of the Reading Beds. These sections seem to indicate a rapid lateral change in the Reading Beds and an unconformable overlap by the London Clay, not previously noted in this part of the London Basin.

From Hertford to Great Amwell the Tertiary escarpment follows the right bank of the Lea, but to a great extent is buried under Drift deposits. Reading Beds, however, are visible in a pit situated in the small valley that extends from the east end of Hertford to Little Amwell. Here an 8-ft. section shows lilac silty clay, passing down into white sand with glauconite. At a higher level, behind Fox Hole Farm, an obscured brickyard appears to be in the London Clay. Across the gorge of the Lea, at Great Amwell, the Tertiary escarpment continues along the south side of the Ash, but here also it is buried under Drift.

At Great Amwell the Lea, having breached the escarpment, turns southwards and flows over the dip-slope of the Tertiaries. London Clay covers some square miles to the west of Broxbourne and Cheshunt and is mostly under plantations. On the east side of the Lea opposite Hoddesdon and Cheshunt there is a strip of bare London Clay between the river flat and the cap of boulder clay, but no sections exist on either side of the river.

In the area surveyed by Mr. Bromehead, the Thanet Sand and Woolwich Beds maintain their usual characters, but it is noticeable that Messrs. Priest and Stamp have detected fossils in the Bottom Bed near Swanscombe.[2] The same authors have described the Blackheath Beds of the Swanscombe outlier.

[1] 'Notes on the Chalk of the Medway Valley, Gravesend, etc.,' *Proc. Geol. Assoc.*, vol. xxix, 1918, pp. 68–105.

[2] 'Geology of Swanscombe Eocene Outlier,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 187–199.

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These beds are so attenuated in this district that they were not indicated on the original 1-in. map. Even in the present 6-in. survey it has not been found possible to detect them everywhere; for example, on the west side of Swanscombe Wood the London Clay is shown as resting directly on Woolwich Beds. In the next large Tertiary outlier to the east, that of Shorne and Cobham, the Blackheath Beds reappear in force, at least 20 ft. of pebble beds and a few feet of sand being visible in sections. Here, therefore, this division has a development similar to that in the type area of Blackheath and Bexley. No cause has yet been suggested to account for its great attenuation in the intermediate area. The London Clay is the highest Tertiary formation in the district.

PLEISTOCENE.

In the area mapped by Dr. Sherlock the Chalky Boulder Clay with accompanying fluvioglacial sand and gravel covers most of the high ground. However, north of the Lea the Chalk rises to the surface between Woodhall Park and Sacombe, and the usually continuous sheet of drift is reduced to patches on the hill tops. The sand and gravel as a rule underlies the boulder clay and generally crops out in the slopes of the valleys, while boulder clay covers the plateau; but as the sand and gravel is in thick lenticles, it is absent in some parts and in others so thick that it extends on to the plateau. A large pit, south-east of Hertford, shows 5½ ft. of sand and gravel on 16 ft. of Chalky Boulder Clay, and below this about 14 ft. of sand and gravel resting on chalk. Here there is gravel above as well as below the boulder clay, and it seems probable that the clay is not the main mass, but a discontinuous band that appears sometimes below and sometimes within the gravel, as at Hertingfordbury, Watton-at-Stone, and the Ware section previously described.[1]

The fluvioglacial sand and gravel borders the Lea Valley on the western slopes from Hoddesdon to Cheshunt, and its level falls with the valley. South of the Lea, areas of clay with pockets of gravel are found on the top of the plateau at Little Amwell. They are characterised by the absence of the far-travelled pebbles, so common in the fluvioglacial gravels, and are composed mainly of flint-pebbles derived from Tertiary deposits. They contain also pebbles of white quartz and, occasionally, of Lower Greensand chert, both constituents being probably of Tertiary origin. With the gradual fall of the surface southwards the patches of clayey gravel become partially overlain by boulder clay, but they are always relatively higher than the adjacent fluvioglacial sand and gravel.

In the Lea Valley a terrace appears at Great Amwell. The northern boundary makes a feature extending across the valley and covered by fluvioglacial gravel probably marks a Reading

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 31. Nos. 1 and 3 in the section there given are identical.

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Beds feature. The terrace has been followed along the west bank of the Lea southwards as far as Cheshunt. Excavations in its sand and gravel show sections identical with those in the fluvioglacial deposits. The difference between them is firstly, position; and secondly, as recorded at Hoddesdon by Mr. S. H. Warren,[1] the presence in the terrace gravel of flint implements. Brickearth covers parts of the terrace and has yielded bones of mammoth, reindeer and some other animals, and flint implements. It seems probable that the terrace may prove to be of Taplow age.

At Cheshunt small areas of blue and black clay are recorded by the nurserymen where one would expect gravel. So far no sections are available, but it is not unlikely that the clay is contemporaneous with the Arctic Bed found by Mr. Warren[2] at Ponder's End, lower down the Lea.

Mr. Bromehead finds that round Darenth Wood and Swanscombe Park there are patches of "Plateau" gravel. These consist of materials derived locally and from the south, and differ markedly from the gravel of Shooter's Hill, for which a Pliocene age has recently been claimed.[3]

The river-deposits of the Swanscombe neighbourhood had been carefully investigated by Messrs. R. Smith and H. Dewey previous to the survey.[4]

Although on the Essex side of the Thames the usual three terraces can be detected and were mapped by Mr. T. I. Pocock 18 years ago, on the south side there appears to be a continuous deposit from about the 50-ft. level to the bottom of the buried channel. This deposit is best known in the Crayford-Erith area, where many deep sections have been available for study. It will probably be found advisable to designate the river-gravels of the Dartford Sheet as the "Swanscombe" and the "Crayford" terraces, the former being equivalent to the Boyn or 100-ft., and the latter to the Taplow or 50-ft., and the Flood-plain terraces.

Besides the bedded river-gravels and brickearths, there are tumultuous deposits, found in several of the valleys tributary to the Thames, consisting of chalk-rubble, gravel and brickearth. These were evidently formed at a time when the topography was approximately that of the present day, since they occur along existing stream-valleys and depend for their composition on the strata bordering the valleys. Where Chalk crops out they consist of a rubble of chalk fragments, sometimes re-cemented, to which the term Coombe Rock has been applied; in the neighbourhood of Tertiary outliers they are brickearths

[1] *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 225.

[2] *Op. cit.*, pp. 213–217.

[3] Leach, A. L., 'Supplementary Notes on Geology of Shooter's Hill,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 127–132.

[4] *Archæologia*, vol. lxiv, 1913, pp. 177–204; vol. lxv, 1914, pp. 187–212.

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formed of re-sorted Tertiary material and with difficulty distinguished from those beds *in situ*; where patches of Swanscombe Terrace gravels occupy the high ground they are essentially gravels. The varieties of composition are so intermingled that it is impossible to map them separately, and it is proposed to include them under the term "Coombe Deposits." From the contained fossils and implements and from the manner of accumulation the period of formation appears to be the end of the Taplow stage, when the semi-arctic conditions of the Mousterian culture prevailed.

ECONOMICS.

The chief industry of geological importance is the manufacture of Portland cement. Along the river-bank from Stone to Gravesend chalk quarries for this purpose are almost continuous, and the operating companies are being forced to obtain their chalk from localities further and further inland. The Associated Portland Cement Manufacturers are also working the London Clay of Swanscombe Wood in a huge pit; the clay is made into slurry on the spot and piped to the works.

The Erith moulding sand (Thanet Sand) was worked extensively during the war, and the industry is still of great importance.

The Swanscombe Terrace gravels are largely dug for concrete-making and other purposes.

Over much of the area the Bottom Bed of the Woolwich Series is strongly impregnated with iron-oxide. There are some indications of an ancient "bloomery" working this ore in Lord's Wood, Green Street Green.

2. Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.
E. E. L. Dixon, B.Sc., A.R.C.S.
T. Eastwood, A.R.C.S.
T. H. Whitehead, B.Sc., A.R.C.S.
T. Robertson, B.Sc.
} Geologists.

During the past season, work in the Stafford Sheet (139) and in the north-western part of the Wolverhampton Sheet (153) has been continued by Messrs. Dixon and Robertson in the neighbourhood of Newport, Stone and Stafford. In the Dudley Sheet (167) Mr. Whitehead has mapped part of the mining district and its western border, lying between Tipton, Cradley and Kingswinford; while in the Birmingham Sheet (168) Mr. Eastwood has surveyed the south-western suburbs of that city and the ground extending westward towards Halesowen.

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CAMBRIAN.

The oldest rocks in the district examined by Mr. Eastwood are the Cambrian quartzites of the Lickey Hills, the northern portion of which falls, at Rubery, within the Birmingham Sheet. The mass consists of quartzite, similar to that of Hartshill, near Nuneaton. The beds strike approximately north-and-south, *i.e.*, parallel to the ridge, though the dip is very inconstant. Neither the top nor the bottom of the quartzite is exposed, and so far the quartzite has yielded no fossils; but on lithological grounds the Lickey Quartzite is regarded as of Lower Cambrian age and equivalent to the Park Hill and Tuttle Hill series of Warwickshire.

SILURIAN.

The Lickey Quartzite is succeeded unconformably by sandstones, varying from a grey-white compact rock, very like the underlying quartzite in appearance, to open-textured reddish sandstone, occasionally calcareous. The basal bed frequently contains boulders and pebbles of the underlying quartzite, as may be seen in the quarries on the south side of the main road in Rubery village. Casts of fossils are fairly abundant, and establish the age of the sandstones as Upper Llandovery. Up to the present, Tarannon Shales have not been found in this area, and the Llandovery Sandstone appears to be succeeded at once by shales, clays, and mudstones, with thin bands of limestone, and by compact sandstone, all referable to the Barr or Woolhope Beds of the Wenlock. The only section in them is that afforded by Callow Brook, the stream in the Asylum grounds at Rubery, where they pass beneath the Halesowen Beds of the Upper Coal Measures.

The outcrops of Silurian rocks at the Castle Hill and at the Wren's Nest, Dudley, and at Turner's Hill near Sedgley (Sheet 167) have been surveyed by Mr. Whitehead. Of these, the lowest beds occur in the cores of the Castle Hill and Wren's Nest domes, and consist of Wenlock Shales. These are followed by the well-known Wenlock or Dudley Limestone, which consists of two bands separated by flaggy and nodular limestones and mudstones. Both these bands have been almost completely quarried away at the outcrop, though mining for the limestone still continues. The Lower Ludlow Shales, consisting of mudstones with bands and nodules of limestone, succeed the Wenlock Limestones. At Dudley the area occupied by the outcrop of these beds has been found to extend farther south than is represented on the geological maps hitherto published. They occupy the surface in the allotments south-west of the Priory, near the Grammar School, and in the grave-yard of St. James's Church, Eve Hill. In an exposure in a ditch to the west of the Grammar School playing-field the dip is south-west, whilst to the east of the playing-field it is east or a little south of

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east, indicating an approach to the southern termination of the Wren's Nest dome.

Mr. John Hughes has supplied details of a shaft and bore-hole sunk within the site now occupied by the Dudley Union Workhouse. The following is an abstract of the section :—

	Ft.	in.
Measures to top of Fireclay Coal	54	4
Fireclay Coal	2	0
Rock, batt, clod, etc.	24	9
Bottom Coal (four coals with partings)	10	0
Fireclays, binds, rock, etc.	57	6
Mottled ground	3	6
Red ground (Borehole)	4	6
Red rock (Borehole)	5	6
Red parting (Borehole)	0	6
	162	7

It is possible that the mottled and red measures at the base of the section may be Ledbury Passage-Beds. If this is the case, the Aymestry Limestone must lie at no great distance from the surface between the Workhouse and the Wren's Nest. This section may be compared with that of the Trial Pits at Shaver's End, referred to by J. B. Jukes,[1] where 68 ft. of measures were found between the Bottom Coal and a blue clunch believed to be the top of the Silurian.

At Turner's Hill and Ellowes Park the following beds are exposed :—

6. Ledbury Passage-Beds.
5. Temeside Shales.
4. Downton Castle Sandstones.
3. Upper Ludlow Shales.
2. Aymestry Limestone.
1. Lower Ludlow Shales.

Of (1) only a small portion is poorly exposed in a little quarry on the west side of Turner's Hill. The Aymestry Limestone (2) is exposed in the same quarry, and contains the characteristic fossil, *Conchidium knighti*, represented by small individuals. The outcrop of the limestone extends only a few yards to north and south of the quarry, being truncated in both directions by faults. Both (3) and (4) are poorly exposed in the western scarp slope and near the summit of the hill; whilst (5) was recognised from the fragments ploughed up in a field immediately to the south-east of Turner's Hill Wood. A bed believed to be one of the Temeside Bone-Beds was found in place in the ditch forming the southern boundary of this field. In the adjoining field to the south large fragments of highly micaceous, purple

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 83; also *Vert. Sect.*, Sheet 18, No. 36.

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and green sandstones belonging to the Ledbury Passage-Beds (6) were found, thrown up by the plough. The Passage-Beds crop out in Ellowes Park also, and are well exposed in an east-and-west stream-course near Ellowes Park Farm.[1]

CARBONIFEROUS : COAL MEASURES.

Near Dudley, on the western margin of the South Staffordshire coalfield, the delimitation of the outcrops of the Middle Coal Measures, and of the various members of the Upper Coal Measures, has been continued by Mr. Whitehead.

The Etruria (Old Hill) Marls occupy the higher ground around Brierley Hill and Scott's Green, and are brought in by the Brierley Hill fault-trough. They also extend northward along the western margin of the exposed coalfield from the junction of the Brockmoor and Western Boundary faults at Brettell Lane nearly to Straits Green, the boundary of their outcrop to the east being determined largely by the Brockmoor and Shut End Faults. In general the Etruria Marls of this part of the coalfield appear sandier, and the marls of a duller purple colour, than around Old Hill and Oldbury.

The Halesowen Beds are nowhere preserved in the area surveyed, with the possible exception of some coarse greenish sandstones exposed in the brook north of Conqueror's Farm, Straits Green. If, as their characters suggest, these beds belong to the Halesowen group, they must be bounded on all sides by faults, as they abut, on the west against the upper portion of the Keele Beds, and on the east against the Middle Coal Measures.

The Keele Beds occupy the eastern half of Himley Park, and near the Straits form a shelf-like feature between the high ground formed of the Hamstead Beds to the north-west and the Western Boundary Fault to the south-east. They consist chiefly of red marls and sandstones, a 'pellety sandstone' or limestone breccia (conglomeratic cornstone) occurring in the cutting of the mineral railway in Himley Wood. There are at present insufficient data to determine what proportion of the Keele group is present at the outcrop in this area, or to establish the local thickness of the group.

Hamstead Beds.—These beds,[2] consisting of a lower Calcareous Conglomerate Group and a higher Breccia Group, occupy a strip of ground extending from near Kingswinford to Brettell Lane. The outcrop is bounded on the east by the Western Boundary Fault, and is separated from the Trias on the west by another fault. Only one band of calcareous conglomerate is recognisable, of which exposures occur north of Bromley Lane and near Buckpool. Another area of the Calcareous Conglomerate Group, with three conglomeratic horizons, comes in

[1] W. W. King, *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 92.

[2] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, pp. 112–115.

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above the Keele Beds near the Straits, and the examination of these, together with the overlying Breccia Group, has been begun around Baggeridge and Gospel End.

North of Halesowen, in ground mapped by Mr. Eastwood, a small tract of highly-inclined Middle Coal Measures, including members of the Thick Coal, with the Gubbin Ironstone and the Heathen Coal, is being worked by a day-hole at Cockshot Lane, south-west of Blackheath. The ground is obscured by drift, and apart from the small coal-workings there are no exposures, though it is evident, since the Halesowen Beds come on east of Cockshot Lane, that a fault, described by Jukes as the Russell's Hall Fault, must intervene, as shown on the old 1-in. map (62 S.W.). The succession as far west as the Dudley canal is regarded as normal—the strata exposed at Coombes Wood Tube Works are believed to belong to the base of the Etruria Marls—though another fault, with a westward downthrow, may come in beyond, introducing beds half-way up in the Etruria Marls.

South of Halesowen there has been no exploration in the concealed coalfield since the Manor Pit was abandoned many years ago. The coals are believed to deteriorate rapidly in a southward direction.

The Etruria Marls call for little comment. Beds high in the succession are exposed in the brick-pits north-east of Halesowen station, where they consist of the usual dull-red marls and conglomerates (espley rocks), with occasional thin bands of coal. Good sections in espley rocks may be seen on Mucklow Hill, where the Russell's Hall Fault brings them against the Halesowen Sandstones.

The Halesowen Sandstones consist of sandstones interbedded with clays and shales, including thin seams of coal and at least two bands of Spirorbis limestone. When fresh, their prevalent colour is grey, though the sandstones usually weather buff or brown and are occasionally stained red, while the argillaceous beds range from white to almost black. The beds are sometimes olive- and chocolate-coloured, especially at the base and near the top of the group. The sandstones are occasionally both pellety and pebbly; the latter condition is especially marked in the basal sandstone, which in places so closely resembles an espley rock of the Etruria Marls that it is difficult to distinguish between the two groups.

The Spirorbis limestones of this group are grey or dirty white in colour, in contrast with the blue and blue-grey limestones of the overlying Keele Beds. The lowest limestone in the Halesowen area was at one time worked about 400 yds. east of Manor Farm, and apparently occurs as a flaggy band, 8 ins. to 1 ft. in thickness, immediately above a bed of sandstone. The same band is represented by debris on a dump from an air-shaft to the canal-tunnel at Lapal House, Moor Street. Its position in the Halesowen group is about 100 ft. above the base. During the excavation of the sewers for some new houses between Hayley Green

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and Hasbury (south-west of Halesowen) a similar bed was encountered. There *Spirorbis pusillus* was abundant and of unusually large size. In addition to the characteristic fossil, spines and scales of a fish of Acanthoid type are present, along with fragments of coal.

Higher in the succession, and probably not more than 150 ft. below the top of the Halesowen group, is another Spirorbis horizon. This may be seen *in situ* in a little tributary 300 yds. south of Illey Mill. The limestone is an 8-in. band of compact rock lying in a thin belt of clays between two sandstones, the lower of which is exposed in the brook by Illey Mill. Although the rock as a whole is compact, it is frequently made up of fragments of white limestone set in a matrix of grey limestone of equal hardness. *Spirorbis* is not abundant, but it occurs in both matrix and fragments. The locality mentioned above was first discovered by Dr. W. Gibson, and was afterwards described by the late Prof. Lapworth. During the past season, pits yielding fragments of similar limestone have been discovered between Illey Brook Farm and Illey Hall Farm. What is believed to be the same bed occurs in place in a ditch 200 yds. north-east of Warstone Farm near Lower Illey.

Several seams of coal occur in the Halesowen group, but as a rule they are very thin and impersistent. Attempts to work one or other of them have been made at the northern end of Offmoor Wood (Sheet 167); also near Rubery, and at California, but without success.

Sections in various portions of the sequence may be seen in the streams flowing northwards near Halesowen; but east of that town much of the ground is obscured by drift. Near Rubery, intermittent sections showing sandstones, clays, and coal, may be seen in the stream at Balaam's Wood, and in Callow Brook in the Asylum grounds. Recent excavations at the north end of the Asylum (Rubery Hill) exposed a seam of coal about a foot thick, associated with grey clay containing small fragments of fossil wood, and dipping westward off the Llandovery Sandstone.

The red rocks succeeding the Halesowen Sandstones and unconformably overlain by the Trias were originally classed as 'Permian of Salopian type.' In the South Staffordshire district, as in other areas in the Midlands, it is becoming increasingly clear that the whole of these beds must be relegated to the Carboniferous System. They consist of argillaceous and arenaceous sediments in which red is the prevailing colour, and the lower portion is characterised by occasional bands of bluish Spirorbis limestone. It is to this group that the name Keele Beds is applied.

The junction of the Keele Beds with the Halesowen Sandstones appears to be conformable, and the base is frequently marked by sandstones of dark lavender tint, such as are seen in Breach Dingle, near Romsley. These are succeeded by red

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marls and sandstones with thin bands of bluish limestone containing occasional specimens of *Spirorbis*. The band found by Mr. Cantrill[1] near Wassel Grove and believed to be about 50 ft. above the base of the group has not been located in the Romsley area. Another band, about 350 ft. above the base of the group, first discovered by Mr. Cantrill (*op. cit.*) near Offmoor Wood, may be seen in a fragmentary condition in a gully 200 yds. north-east of St. Kenelm's Hall, and in Breach Dingle at a point 400 yds. north-north-east of St. Kenelm's Rectory, while it is abundantly represented in the debris from the pipe-line of the Birmingham aqueduct (Elan supply) at the south-east corner of Offmoor Wood. What is possibly the same band has been recorded at Frankley reservoir, and it has since been seen in Egghill Dingle, Long Kettles Wood, near Gannow Green, at Hollymoor Asylum, and near Bartley Green.

Hamstead Beds.—Higher in the succession, the marls occasionally take on an even brighter red tint than usual, whereas the sandstones, although often red, are frequently brown or yellowish. In addition to change of colour these sandstones locally become markedly calcareous and highly charged with small rolled pellets of inorganic limestone, in addition to which occasional small fragments of organic limestone, calcareous mudstone, and other foreign matters occur. In the past these conglomeratic 'cornstones' were burnt for lime. Though similar rocks are found in the Keele Beds below, the position and general characters of the main belt of these calcareous sandstones link them up with the limestone conglomerates of the Hamstead Beds, found farther north at about the same position in the sequence.

Though the Hamstead Beds, which occupy an intermediate position between the Keele Beds and the trappoid breccia of the Clent Hills, are well exposed in natural sections near Romsley, they make much more striking features around Frankley, where they are surmounted by a capping of breccia—the outlier of Frankley Beeches.

The Clent Breccia has been so well described by Mr. Wickham King[2] that there is little to add here. Up to the present the evidence is in favour of general concordance between the breccia and the beds below, while the relation between it and the overlying Trias is one of marked unconformity.

Though giving rise to prominent features, it is, as a rule, not well exposed, especially in the main mass forming the high ground extending from the Clent Hills to Rubery. In the detached areas good road-sections are to be seen at Merritt's Hill near Northfield, and in the Halesowen-Birmingham road east of Quinton. In addition to the localities already known, a small outlier of the breccia has been found north-west of Bromwich

[1] *Geol. Mag.*, 1909, p. 449.
[2] *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 97.

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Wood, between Frankley and Bartley Green. It is about 400 yds. in length by 200 yds. in breadth, and probably does not exceed 20 ft. in thickness. Though there are no sections in it, the ditches and the debris on the ploughed fields afford ample evidence of the presence of breccia.

TRIAS.

In the district of Newport (Salop) Mr. Dixon finds that, as elsewhere, the several lithological types on which the original classification of the Trias was based are not rigidly confined to the subdivisions named after them. Thus, mottled and brick-red soft sandstones, devoid of fragments of old rocks, and indistinguishable from the beds that make up the Lower and Upper Mottled subdivisions of the Bunter, are found also in the Pebble Beds and in the Keuper Sandstones. Thick beds of massed pebbles are certainly confined to the Pebble Beds; but scattered pebbles, and, more especially, subangular fragments of hard rocks, occur in the higher part of the Lower Mottled subdivision, and still more frequently in the Keuper Sandstones. The same features characterise special lithological types. In parts of the Midlands, fresh pink felspars, in the form of small worn crystals and cleavage-fragments, distinguish the base of the Keuper Sandstones from higher zones and also from Bunter beds; but near Newport such felspar-fragments occur also at various horizons in the latter formation.

Notwithstanding a community of character, in this district Bunter and Keuper are quite probably unconformable. Fortunately the junction is exposed at several places along the bold feature caused by the erosion of the soft Upper Mottled sandrock below the hard Keuper sandstones; in all sections it is either obviously or possibly sharp, and in some is uneven. Also the base of the Keuper is usually conglomeratic, though the fragments may be scattered sparsely along a single line. It has not been possible to determine variations in the thickness of the Upper Mottled formation, but that of the Keuper Sandstone varies from about 20 ft. near Broad Hill, east of Newport, to 400 ft. west of Blymhill; while a boring for water now being put down near Ivetsey Bank has proved 600 feet without reaching the base. The thinning near Newport may be due to overlap of basal members, present at Blymhill and Ivetsey Bank, by higher members, in which case the base, in places at least, is unconformable. Further evidence, however, is needed owing to an uncertainty as to the significance of variations in character and thickness in 'continental' formations such as these, and the known frequency and persistence of horizons of contemporaneous erosion in such formations.

Near Stone, Mr. Robertson finds that the Bunter Pebble Beds with their pebbly sandstones cover the area around Swynnerton, with the exception of a narrow band of Keuper

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Sandstone and Marl, thrown down along the eastern side of the Apedale Fault. Another fault, running east-north-east through the middle of Swynnerton Park and thence by Darlaston and Oulton to Moddershall, throws down Keuper Marl to the south. An inlier of the Keuper Sandstone occurs in the valley of the Scotch Brook, north-east of Stone.

A strip of Pebble Beds runs south-east from Moddershall to Cotwalton. Here, as to the north, in the Stoke-on-Trent Sheet (123), the Pebble Beds seem to be directly overlain by Keuper Marl.

From Swynnerton Park for 8 miles southward to Haughton, dark red and purple Keuper Marl, usually without skerry-bands, is the only 'solid' rock to be seen. Except close to the boundary-fault at Swynnerton Park it is practically horizontal. Good exposures are visible in many places, the higher ground being for the most part free from drift.

Butterton and Swynnerton Dyke.—It has long been known that an igneous dyke cuts the higher parts of the Coal Measures on the southern margin of the North Staffordshire coalfield and extends southwards through the Triassic rocks to the west of Stone.[1] In the southern part of its course this dyke has now been traced in detail by Mr. Robertson from Swynnerton to Heamies Farm near Norton Bridge—a distance of about 3 miles. Its approximate position was detected on Pebble Bed ground just north of Swynnerton village. Thence it bears a little east of south, past the west side of Swynnerton Hall and through Swynnerton Park. Halfway through the park the outcrop is shifted about 150 yds. to the east-north-east, just where the fault already mentioned as throwing down the Keuper Marl is estimated to cross the ground. Whether this shift is due to a displacement of the dyke by the fault or to a diversion of the dyke along the fault is not known.

A short distance north of the fault a poor exposure in a coppice shows the dyke in contact with and enclosing pieces of Pebble Bed (Bunter) sandstone. In Doles Coppice, 150 yds. south of the fault, the dyke (or one branch of it) is 3 to 4 ft. thick, seems to be nearly vertical, and is seen in contact with Keuper Marl.

South of this point the dyke-outcrop traverses no other formation. It appears to run undisturbed to Pilsen's Wood, west of the Highlows, where in one place it has broadened out to an estimated width of over 100 yds. Some of the hand-specimens obtained here exhibit a much more coarsely crystalline texture than any noticed farther north. There are also exposures of much-decomposed material a short distance south of the wood. Nothing more of it is seen *in situ* until we reach the north side of the hill on which Heamies Farm is situated. Here three distinct branches of the dyke are visible, approximately in line

[1] 'The Geology of the Country round Stoke-upon-Trent' (*Mem. Geol. Surv.*), ed. 2, 1905, p. 55.

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with the exposures farther north. Each of these branches is 3 to 4 ft. in thickness, with a very steep dip to the west. The most easterly and most westerly branches are respectively about 24 ft. and 240 ft. from the middle one. South of this point the dykes either thin out or cease to be traceable.

West of the South Staffordshire coalfield, from Wordsley to Himley, Mr. Whitehead finds that the Trias outcrop is divided into irregular blocks by a system of faults that would seem to be the result of adjustments accompanying, or following, the movement along the Western Boundary Fault. A borehole for water at Stourbridge Workhouse,[1] begun in the Upper Mottled Sandstone, reached the Pebble Beds at a depth of about 130 ft. As the base of the Pebble Beds on Cooknell Hill, to the south, is well over 300 ft. above sea-level, it is clear that, immediately to the south of the workhouse, there is a fault that throws the Upper Mottled Sandstone on the north against the Pebble Beds and Lower Mottled Sandstone on the south. This fault appears to run westward to the Pebble Bed escarpment at Lawneswood, where it may join a north-and-south fault, with westward downthrow, known as the Stapenhill Fault. East of this fault, and south of the 'Workhouse Fault,' the ground is occupied mainly by the Pebble Beds, the Lower Mottled Sandstone emerging in small patches against the faults to the east and west. North of the Workhouse Fault, around Kingswinford, Wall Heath, and Himley, the Upper Mottled Sandstone occupies most of the area, the Pebble Beds emerging at the Ridge Hill, at Kingswinford, in Himley Park, and in small patches brought in by faults.

Both the Upper and the Lower Mottled Sandstone seem uniformly brick-red in colour in this district, the 'mottled' character appearing only when the passage into the Pebble Beds is approached.

The Triassic rocks examined by Mr. Eastwood in the Birmingham area consist of the Bunter Pebble Beds, the Upper Mottled Sandstone, the Lower Keuper Sandstone, and the Keuper Marls.

The Bunter Pebble Beds form a continuous belt between Smethwick and California near Harborne, but much of the ground is obscured by drift. From California southward nearly to Northfield they are cut out by a fault that brings in Keuper Sandstone against Keele and Hamstead Beds; but they come in again between the latter place and Rednal. On the north, shingle-beds are abundant; but on the south the bulk of the formation consists of soft red sandstone with occasional small pebbles.

The Upper Mottled Sandstone, which has furnished considerable quantities of moulding sand in Birmingham, may be seen at several places around Hockley and Summer Hill. Until just recently the sand was also obtained from a pit in Dale Street,

[1] Information from Mr. W. Wickham King.

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Smethwick, a locality much farther west than this formation is represented on the old 1-in. map (62 S.W.).

The Keuper Sandstone forms the higher ground of Birmingham and extends beyond the southern margin of the area mapped. Permanent sections are rare; but the formation may be seen in the canal-cutting south of the city, also near Weoley Castle, around Northfield, and in the Cofton railway-cutting. As a rule the sandstone is harder and browner than the Bunter, and can thus be distinguished from the rest of the Triassic sandstones; but in some cases red pellety sandstones similar to those of the Keele Beds render identification of poorly-exposed portions rather doubtful.

The Keuper Marl may be seen in numerous brick-pits to the east and south-east of Birmingham; but the actual junction with the Keuper Sandstone is not visible on account of a fault the existence of which has been proved by borings.

GLACIAL.

In continuation of the work commenced last year (1919) in the Newport (Salop) district, Mr. Dixon has found it possible to distinguish between the deposits of sand and gravel formed when the whole area lying below the 300-ft. contour was flooded beneath the waters of an ice-dammed lake and those earlier ones thrown down or laid bare as the ice-front retreated across the district. Last year some of the latter were attributed to escaping lake-waters. It is more probable that all the eskers and fan-like or delta-form deposits have originated in the ways suggested in the case of certain similar formations elsewhere, viz., that the fans and deltas have been thrown down along the ice-front at the mouths of englacial or subglacial streams during pauses in the retreat, and that the eskers show the courses of the streams. The eskers may have been formed at the mouths of the streams during the periods of more rapid retreat, or they may have accumulated in the stream-channels within the ice and have been merely bared by the retreat. The evidence obtained about Newport is open to either interpretation, but as regards the broad outline of the hypothesis it is unequivocal. The fans and eskers fall naturally into several linear series, each of which may be compared with a string carrying a few beads—the fans. With few exceptions any fan in a series is represented by a similar fan in each of the other series, and these similar fans are found to be so placed that the line connecting them, which according to the hypothesis gives us the position of the ice-front during their deposition, agrees with that position as inferred from the forms and orientations of the fans. Further, in several cases fans are bordered by hollows or by dry channels draining away from them, which seem to demand for their explanation torrents of water pouring off the fans.

The longest, widest, and most continuous of the series that have been recognised up to the present enters the southern

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margin of the area examined at Blymhill, 5 miles south-east of Newport, and follows a north-westerly course past that town, where it skirts the northern end of the high Bunter ground bordering the Coalbrookdale coalfield, to leave the area at Lane End, a run of 10 miles. This series, by its continuity and the obvious resemblance of two of the swellings along it to deltas or fans, gives the clue to the interpretation of the whole. Several small series run almost due west into it, or may be said to branch to the east from it.

The other bands that have been recognised, three in number, lie to the north-east of the major series, and parallel to it, the farthest removed following a line through Littleworth, High Offley, and Knighton (5 miles north-east of Newport). They pass up and down hill in the manner characteristic of eskers.

South of the latitude of Newport these minor series cannot be traced, and the swellings noticeable along the major series, indicative of pauses in the ice-retreat, are small and ill-defined. But at Aqualate Park, Newport, and thence east-north-eastward for 4 miles to Prospect Hill, Knightley, a line of fans in all the series points to a marked pause when the ice-front reached that line. At a mile or so to the north-west another line of fans shows that the retreat was stayed still longer when a line through Chetwynd Park and Littleworth was reached. The fan thrown down during this pause by the main stream is the largest and best example in the district. The alignment of the ice-front during this pause was appreciably more north of east than during the preceding pause. A third pause is marked by a line of smaller fans between Lane End and Knighton, and further swinging-round of the ice-front is proved by the north-north-easterly trend of the line.

Though the lines of fans mark stationary positions of the ice-front, they are quite unlike the 'terminal moraines' that have been recognised in various other regions. In fact it is noteworthy that the deposits at the stationary ice-front have been almost entirely localised to a few places where streams have debouched.

The ice-dammed lake that at a later period covered the area up to the 300-ft. contour has left traces of its shore-line in the form of terraces of sand and gravel, and, much more commonly, in a more or less marked notch or change of slope. Its western and northern limits have not been found; eastward it had a small overflow at Gnosall into the Trent basin. Deposits of laminated clay have been found at many places within its area, but appear to be connected with the fans of the earlier period previously described. They may have been laid down in small temporary sheets of water held up between the ice and the high ground during the retreat across the district.

North of Stone Mr. Robertson finds that the Trent valley is lined with boulder-clay, of unknown thickness, over which

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gravels rise to a height of about 30 ft. above river-level. Valley-gravels are well developed along the Trent and Sow valleys.

The Sow basin, north of Stafford, shows extensive stretches of gravel and sand, but very little boulder-clay. The broad pre-Glacial valleys have been nearly filled with sand and gravel brought down by the streams in late-Glacial or early post-Glacial times, when an enormous quantity of water was flowing. This sand and gravel collected in the side valleys also, *e.g.*, along Gamesley and Doxey Brooks. The modern shrunken rivers now run in approximately the same channels, but beyond the alluvium a slope, often steep, and sometimes 20 ft. or more in height, marks the edge of a sand and gravel terrace. These terraces are well marked along the Sow valley and are sometimes very persistent, *e.g.*, between Great Bridgeford and Stafford. The Sow now meanders over a flat peaty alluvial plain, beyond which on either side a bank of sand and gravel rises and masks with its irregular surface the contours of the original pre-Glacial valley.

An interesting channel, probably of glacial origin, is to be seen in the valley of Scotch Brook north-east of Stone. Just south of Oulton Mill the stream, which runs in a narrow steep-sided valley of Keuper sandstone, turns sharply to the west. About 200 yds. farther on it turns southwards again, round the end of a Keuper sandstone cliff. On the outer side of the first bend the valley widens out a little, and a series of clays, sands, and gravels has been deposited on the side of the sandstone slope to a height of about 30 feet above the present stream-level. There would appear to have been a block at this point, due either to the narrowness of the gorge below or to the fact that the valley beyond had not up till that time been excavated sufficiently deeply.

Overflow probably took place first of all due southward over the top of the sandstone barrier, behind which there is much gravel on the southern slopes. Finally, however, the gorge would be excavated sufficiently to allow the whole discharge to pass through it, leaving the sands and clays banked up at the side of the entrance.

No traces of drift have been found in that part of the South Staffordshire coalfield surveyed by Mr. Whitehead during the past season. To the west of the coalfield the most conspicuous drift feature is the 'esker' near Kingswinford, described by Prof. W. S. Boulton,[1] which extends, within the area surveyed, from Wordsley to Wall Heath. It forms in places a marked ridge. Exposures in it show sand and gravel, false-bedded, and sometimes contorted; with lenticles of clay, and streaks of carbonaceous material in places. In a sand-pit at Wall Heath, these sands and gravels may be seen resting on horizontal Upper Mottled Sandstone, the surface of which slopes westward at about 10°.

[1] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 1, 1916, p. 25.

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South of the River Stour, and west of the gap made by that river in the Pebble Bed escarpment at Bell's Mill, south-west of Wordsley, a patch of sand, with lenticles of gravel containing many far-travelled pebbles, lies on the Lower Mottled Sandstone at the level of the adjacent canal. North-west of Himley, clay, or sandy clay, with many pebbles, occupies much of the higher ground, and is exposed to a thickness of about 15 ft. in a cutting of the new Wolverhampton Railway north-west of Himley Plantation.

The fields between Himley and Wall Heath are plentifully strewn with pebbles, of which a certain proportion consist of basalt, and of Coal Measure grits.

Much of the solid rock around Birmingham, in Mr. Eastwood's district, is obscured by drift. West of Warley and towards Halesowen the deposit is thin, and consists of clay and sand with some stones; but eastwards thick deposits completely hide the outcrops of the Trias. From Smethwick through Harborne to California the drift has a thickness of about 80 ft. Though the Glacial deposits are extremely variable, their general succession appears to be : (1) a lower series of tough reddish clays (as seen at California), associated with bedded sands and gravels; (2) an upper series of sands, clays, and loams, mainly unbedded. Far-travelled erratics occur in both series, and include many igneous rocks similar to those of the Arenigs; while of those from a less distant source the Rowley basalt is the most readily identified. Fragments of local sedimentary materials, such as espley rock from the Etruria Marls, and sandstone from the Halesowen and Keele Beds and from the Trias, are also common; while in the Longbridge area Lickey quartzite and Llandovery sandstone are present. The former wide-spread distribution of the drift is probably implied by the presence of erratic boulders over the Romsley area, though that district is now practically free from other forms of drift.

3. Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.
R. W. Pocock, B.Sc. } Geologists.
D. A. Wray, B.Sc. }

During the past season the re-survey of Liverpool and its inner suburbs, begun[1] in 1914 but suspended during the war, has been completed by Mr. Wray. The whole of the Liverpool Sheet (96), with the exception of the area occupied by rocks older than the Coal Measures, has now been revised.

In the Wem Sheet (138) the south-western portion around Baschurch, Middle, and Leaton, has been finished by Mr. Wray, while Mr. Pocock has mapped a wide belt of ground between Wem and Hodnet.

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, pp. 11, 12.

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In the Shrewsbury Sheet (152) the north-western margin, traversed by the Severn between Shrawardine and Shrewsbury, has been examined by Mr. Wray.

TRIAS.

In the Liverpool district the 'solid' formations mapped by Mr. Wray are the Pebble Beds and the Upper Mottled Sandstone of the Bunter, and the Basement Beds and Waterstones of the Keuper.

Considerable modification of the original map has been necessary in some parts of the district. Thus the valuable information obtained during the construction of the new outfall sewer[1] from Walton to the Canada Dock fully confirms the original contention ('Summary of Progress for 1914,' p. 11) that the broad belt of Upper Mottled Sandstone shown on the old 1-in. map (79 N.E.) between Walton Hall and Sefton Park is not present. It has also enabled Mr. Wray to locate precisely the position of the main north-and-south faults that traverse the Triassic rocks of Liverpool; and also the base of the Keuper Sandstone, which was found to rest unconformably on the Bunter Sandstone in the tunnel-section under Oriel Road.

The Pebble Beds are well exposed in numerous old quarries at Everton, Aigburth, at West Derby, and also in the extensive cutting on the L. & N.W. Railway at Olive Mount. In the Liverpool District these beds are remarkable for their uniformity.

The Upper Mottled Sandstone consists of soft mottled yellow and red sandstone, and calls for little comment.

The Keuper Basement Beds, wherever exposed, have a gritty sandstone at their base. In the re-survey they have been met with in numerous places at the southern end of the city, and their outcrop has been found to be broken up by numerous parallel north-and-south faults, some of which are visible in the cuttings on the Cheshire Lines Committee's railway to the north of Toxteth and Harrington Docks.

The only exposure of the Waterstones is a narrow faulted outcrop in St. James's Cemetery.

In the south-western part of the Wem Sheet and in the north-western margin of the Shrewsbury Sheet, surveyed by Mr. Wray, it appears that, with the exception of about 2½ square miles on the east of Middle and the north of Pim Hill (an area almost free from drift) the 'solid' geology is largely obscured by a thick mantle of Glacial deposits.

The 'solid' formations mapped are the Bunter Sandstones, the Keuper Basement Beds, the Waterstones, and the Keuper Marl.

The Lower Mottled Sandstone was examined in sections alongside the River Severn at Ford, and also in the village of Ford, where it consists of thinly laminated and fine-grained red sandstones.

[1] The results of the examination of this section are published in *Proc. Liverp. Geol. Soc.*, 1915–1916, pp. 238–251.

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The Bunter Pebble Beds form an outlier at Benthall Cross and Whiston, about half a mile west of Ford. This outlier is shown on the old map (61 N.W.), but has been proved by sections exposed at Benthall Stone to cover a much larger area.

From what is known of the general structure of the district, the Pebble Beds should crop out beneath the broad covering of drift between Nesscliff and Pim Hill on the north, and Ford and Shrewsbury on the south; for the Lower Mottled Sandstone is exposed around Ford, and the Upper Mottled Sandstone on the lower slopes of Nesscliff and Pim Hill; but they were nowhere met with.

The harder beds that characterise the top of the Bunter and have been extensively quarried near Middle (at Webscott, Harmer Hill, and Pim Hill) strongly resemble beds met with in the Ruyton and Nesscliff districts farther west ('Summary of Progress for 1915,' p. 9). In like manner they give rise to a prominent feature in the landscape. They are, however, overlain by white and yellow sandstones, which appear to occupy the same horizon as the Grinshill freestones farther east, and to belong to the Keuper rather than to the Bunter. In the area about Middle the base of the Keuper has, therefore, been taken at the base of these yellow freestones.

It seems highly probable that the harder, dull-red freestones worked in the Ruyton and Nesscliff district represent not only these yellow freestones, but also part of the Upper Mottled Sandstone. As no definite line could be taken as the base of the Keuper at Ruyton and Nesscliff, the dull-red freestones have been mapped as a separate subdivision, and named the Ruyton Sandstones.

Through the whole area the Waterstones are represented by marly and flaggy chocolate-red and yellow sandstones, frequently characterised by small hollows or pores, of the size of a pin's head or of a pea. They are well exposed at Balderton Hall near Middle, and also near the National Schools and Shotton Hall, in the Harmer Hill district.

The Keuper Marl is well exposed in large disused marl-pits to the east of Lea Hall, Harmer Hill, and also at Newton on the Hill and Bilmarsh. At the latter locality it contains a prominent bed of sandstone.

The past year's work has tended to confirm the suggestion made in the 'Summary of Progress for 1915' (p. 9) that the Prees Syncline extends south-westwards to Ruyton and Nesscliff. It is highly probable that the country to the north and east of Baschurch is underlain, not by the Upper Mottled Sandstone, as is indicated on the old map, but by the Keuper Marl. The Keuper escarpment at Middle terminates very abruptly to the north, suggesting a faulted boundary, probably on the line of the powerful north-east and south-west fault well seen to the immediate north of Great Ness. The general effect is to bring the Upper Mottled Sandstone on the south-east against the supposed

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Keuper Marl on the north-west at Prescott, Fenemere, and Middle. The presence of abundant fragments of Keuper skerry sandstone in the drifts of the whole district to the south of Baschurch and Middle tends to confirm this view.

Around Pim Hill and Harmer Hill the structure is complicated by powerful north-and-south faults. One of these faults, which runs immediately east of Pim Hill, carries notable quantities of green copper ore, which was last worked about 50 years ago.

Farther east, the district of Clive, Grinshill, Lee Brockhurst and Hawkstone has been mapped by Mr. Pocock, who finds that all three divisions of the Bunter are present.

The soft, bright red and brown sandstones that form the upper part of the Lower Mottled Sandstone are exposed at Harcourt Park and Rock Hall, near Preston Brockhurst, where they are strongly current-bedded, and are cemented in places by barytes. At one horizon the sandstone is composed of well-rounded millet-seed grains.

The Pebble Beds form the high ground of Besford Wood, Booley, and Stanton, and have been quarried in places, on a small scale, for building-stone. Their base is marked by a bed of calcareous sandstone and conglomerate, which can be seen in the south bank of the Roden east of Lee Bridge, in the lane between Besford and Lee Bridge, and near Harcourt Park. Outliers of the Pebble Beds have been detected at Acton Reynald and Blaze Coppice, near Preston Brockhurst.

The Upper Mottled Sandstone is exposed on the southern slope of Grinshill, and forms most of the high ground at Weston Heath and Bury Walls (north-east of Lee Brockhurst) that was formerly mapped as Keuper Sandstone. No evidence has been found for the east-and-west fault shown on the map as running through Weston.

The upper limit of the Bunter is not well defined, but the line has been drawn to include all the red, fine-grained sandstones within the Upper Mottled division.

The succeeding Keuper Basement Beds consist of fine-grained yellowish to white sandstones, which have been extensively worked for many years at Grinshill as the well-known Grinshill building stone. The quarries show in places a vertical face nearly 100 ft. in height. Quarrying-operations have now ceased on account of the high cost of labour and the great thickness of marl and 'flag-rock' that has to be removed before the building stone is reached.

These white sandstones are well developed near the Red Castle and along the Terrace in Hawkstone Park.

The Waterstones are yellow, brown, and grey flaggy sandstones, evenly bedded, and for the most part of fine grain. They average 20 ft. in thickness at Grinshill, where they are known as the 'flag-rock,' and are used for rough walling and flags; at one time they were employed for roofing also.

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At the base of the 'flag-rock' there is a well-marked bed, averaging 9 in. in thickness, of yellowish sand with black specks of manganese, which is known as 'esk' or 'hess,' a local name for ashes. This bed has been found to persist throughout the area surveyed.

Good sections of the Waterstones and esk-bed are exposed near the obelisk in Hawkstone Park, and also near Marchamley.

The Keuper Marl is of the usual red and grey shaly type, with thin sandstones. The feature separating the outcrop of the Marl from the drift-covered area to the north-west, which was mentioned in the 'Summary of Progress for 1919' (p. 9), has been found to continue north-eastwards towards the Abbey.

The principal fault of the district runs north-eastward through Preston Brockhurst and Lee Brockhurst, throwing down the Keuper Marl on the north-west against the Bunter Sandstones on the south-east, as can be well seen just north of Bridleway Gate Farm near Lee Brockhurst, and at Wixhill near Weston.

Copper ores were formerly worked along approximately north-and-south faults close to Clive Church at Grinshill, also at Yorton Bank, and at Wixhill Hill near Weston.

IGNEOUS INTRUSIONS.

Grinshill and Acton Reynald Dykes.—An igneous dyke, usually only 18 in. in width, has been traced by Mr. Pocock for a distance of two miles from near Holbrook, 2½ miles south of Wem, to the Grinshill Quarries above Acton Reynald. Where it invades the Keuper Sandstone it appears to have ascended along several more or less vertical joints, as four distinct branches have been detected in the hill-side. The dyke is seen again crossing the Upper Mottled Sandstone of the Bunter in a direction 80° east of south in an old lane that leads from the Grinshill road to the quarries. One or other of these branches is probably continuous with one of the dykes at Acton Reynald discovered in 1834 by Murchison,[1] whose observations have been confirmed by information obtained that a dyke passes under the house and tennis-court in a north-westerly direction and forms the side of a well, now built over, in the courtyard. Specimens from this locality have been secured. Murchison mentions another parallel dyke, and also a third, crossing these in an east-north-eastward direction, but no information could be obtained about the two latter.

The rock has been provisionally determined by Dr. H. H. Thomas as an albitised porphyritic basalt, though fresh specimens have since been obtained that may modify this determination.

Dr. Thomas reports that so far as he is aware this dyke is quite unlike any of the others that have been proved to be, or may be, of post-Triassic date.

[1] 'Silurian System,' 1839, p. 295.

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GLACIAL AND RECENT DEPOSITS.

In the Liverpool District mapped by Mr. Wray, numerous borings made in recent years have shown the thickness of the drift to be very variable. Glacial deposits attain their widest development in the south-eastern half of the city.

Along the Mersey shores the boulder-clay forms cliffs 30 ft. high, extending from the Dingle to Otterspool, where it seems to mask a north-and-south hollow in the Triassic rocks.

The Shirdley Hill Sand forms isolated patches preserved in hollows in the boulder-clay. In the neighbourhood of West Derby, where its occurrence has not, it seems, been previously noticed, it attains in places a thickness of over 15 ft. The largest patch occurs around Prince's Park and Otterspool, where it has been dug in comparatively recent times, while it also forms a capping to the adjacent boulder-clay cliffs.

In the south-western part of the Wem Sheet and adjacent margin of the Shrewsbury Sheet, Mr. Wray finds that the Glacial drifts consist of reddish, loamy boulder-clay, with broad spreads of well-bedded gravel and red sand around Stanwardine in the Fields, Baschurch, Broomfields and Montford Bridge. Their thicknesses are extremely variable. Wells and borings have shown them to be 50 ft. thick at Bomere Heath, 100 ft. at Leaton, 96 ft. at Dunn's Heath, and 82 ft. at the Barracks, in the western outskirts of Shrewsbury.

The boulder-clay and the associated gravels consist mainly of slaty Welsh detritus, though granites, apparently of northern origin, and Keuper 'skerry' sandstone, are almost invariably present throughout the district.

Northern erratics appear to be relatively more abundant in the eastern parts of the district. At Leaton, Bicton, Shrewsbury and Preston Montford, the main drift with far-travelled erratics seems to overlie a drift of purely local origin, made up almost entirely of red Triassic sandstone debris.

Shell-fragments are never abundant in the drift, though they have been recorded by Darwin at Shelton Rough, to the immediate west of Shrewsbury, and by Miss Eyton[1] from the now overgrown and disused pits at Merrington Green and Old Wood.

From Ford on the west to Shrewsbury on the east the Severn follows a very meandering course, its total length being nearly 14 miles, while the two localities are only five miles apart. At Ford, in the bed of the river, under a steep bank of boulder-clay, reefs of Lower Mottled Sandstone appear.

The alluvium of the river calls for little comment. It is formed exclusively from the degradation of the drifts and underlying Triassic sandstones. At Ford, Montford Bridge, the Isle, Cross Green, Berwick Park and Gravel Hill, prominent gravel terraces rise 12 to 15 ft. above the level of the recent alluvium.

[1] C. Eyton, 'On the Pleistocene Deposits of North Shropshire,' *Geol. Mag.*, 1870, p. 106.

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These terraces mark an earlier stage in the history of the river. That at Gravel Hill, near Shrewsbury, is intimately connected with an old river-meander, nearly three miles long, which can be traced past Hencott and Ditherington into Shrewsbury. It forms a flat-bottomed and very broad valley, which appears to have been the course of the Severn while the terrace was in process of formation. At a later stage the river cut through the low col between Frankwell and Coton Hill and forsook its former channel, which is now occupied by two insignificant brooks, clearly 'misfits' to the present wide valley. The same process, though not quite so far advanced, is to be seen at the 'Isle,' where a narrow neck, only 350 yds. wide, separates the two ends of a wide meander 4½ miles long.

At the Berth near Baschurch, at Fenemere, and at Eyton, the Glacial sands, which give rise to an undulating and characteristic moundy landscape, are associated with extensive peat-flats.

Farther to the north-east, where surveyed by Mr. Pocock, the high ground extending from Middle to Hawkstone appears to have acted as a barrier to the direct flow of Glacial material from the north-west.

Boulder-clay of a somewhat sandy type occupies most of the low ground south of Grinshill and east of Acton Reynald, the Bunter sandstones appearing only in isolated patches. On the higher ground a few small areas of boulder-clay are found, at Shooter's Hill, near Besford Wood, and around Moston; while the same material covers the ground between Rakepark Lodge and Kenstone, between Weston and Hodnet.

A spread of gravel occurs west of Lee Brockhurst, and sand covers a considerable area round Moreton Corbet. Both these deposits may be connected with an early stage of the River Roden.

4. Cumberland, Westmorland and Furness.

Headquarters: Whitehaven, Cumberland.

B. Smith, M.A., District Geologist.
T. Eastwood, A.R.C.S. } Geologists.
J. Maden, M.Sc. }

Mr. Bernard Smith proceeded to Cumberland early in November to report upon a suitable centre for headquarters, which were finally fixed at Whitehaven. The work of establishing the centre and getting into touch with local interests was then taken in hand. Mr. T. Eastwood, detached from the Midland staff, arrived on December 9th with Mr. J. Maden, whose training in field-work, under the former officer, was commenced on ground that will be some of the first to be mapped systematically in 1921.

Various enquiries as to future prospects in the coalfield north of Maryport and in the iron-ore regions, have been dealt with. Prospecting for hæmatite by boring has been carried on

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extensively during the last few years in the Whitehaven district and as far south as Millom, some of the latest borings being situated at Whitbeck beneath the western shoulder of Black Combe. The search for hæmatite is proceeding in the Vale of Eden also, in an area where abundant fragments of high-grade ore occur in the glacial deposits.

The cores of six borings for iron-ore, three in the Calder Bridge neighbourhood and three near Kirksanton, west of Millom, were examined by Mr. Smith, who discovered grey fossiliferous beds and magnesian limestone in the New Red Series at Kirksanton. More than one boring has been pushed down into fine-grained volcanic rock, riddled with veinlets of calcite, on the assumption that it was Carboniferous Limestone.

Some disturbed and partly-dispersed cores from borings at Hensingham near Whitehaven were examined by Mr. Eastwood.

Detailed records of 14 borings or shaft-sinkings for coal or iron-ore, and abbreviated records of others were obtained. An account of the borings for coal at Bank End and Blue Dial near Maryport, first visited in the early part of the year, and the interesting results obtained, is given in Appendix III., pp. 85–91.

Some of the plans of underground and undersea workings of the Whitehaven Colliery have been transferred to 6-in. Ordnance Sheets.

A series of published 4 miles to 1 in., 1-in. and 6-in. Geological Maps, Vertical and Horizontal Sections, and Survey Memoirs on the district is lodged in the office. These will be available for reference.

Detailed descriptions of the lead and zinc mines of the Lake District, examined by Mr. Eastwood, to form one of the Special Reports on Mineral Resources, are being prepared for publication.

5. Northumberland and Durham.

Headquarters: Newcastle-on-Tyne.

R. G. Carruthers, District Geologist.
C. H. Dinham, B.A.
G. A. Burnett, B.Sc.
F. Marsden, B.Sc.
A. Fowler, M.A., B.Sc., A.I.C. } Geologists.

The new unit allotted to the North-Eastern coalfield began operations towards the close of the year. It was decided that, in the first place, special attention should be paid to the 'Limestone Coals,' as they are the main reserve in this part of England. There is much doubt over the finer points of correlations and structure amongst these rocks, and a revision of the existing maps is certainly called for. Messrs. Burnett and Marsden have begun work in the Scremerston field, south of Berwick, and have completed the preliminary measurements of

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the typical coast-section, in which they have been assisted by Mr. Fowler.

6. Borings for Oil in Derbyshire and Staffordshire.

The progress at the Petroleum Department's borings for oil in Derbyshire and Staffordshire has been carefully followed; Mr. Bromehead has collected geological information from the seven borings in Derbyshire, Mr. Eastwood from those in Staffordshire; several visits have been paid to the sites and many samples examined in the Survey Office. The following table shows the progress from the beginning of 1920 to the time of going to press, May 1921.

Well.	Depth in January 1920.	Depth in May 1921.	Remarks.
	Ft.	Ft.	
Ridgeway -	2,996	2,996	Abandoned January 1920.
Renishaw -	3,645	4,200	Carboniferous Limestone at 4,100 ft.
Brimington -	2,660	4,040	Carboniferous Limestone at 3,000 ft.
Heath - -	2,955	4,009	Carboniferous Limestone at 3,950 ft.
Hardstoft -	3,112	3,112	No change.
Ironville II -	3,570	4,005	Now abandoned.
Ironville I -	2,580	3,655	Still in Carboniferous Limestone.
Werrington -	1,920	—	Fishing.
Apedale I -	1,350	1,350	Abandoned.
Apedale II -	—	3,450	Started September 1920.

From the economic point of view the results have been disappointing. Hardstoft continues to yield about 1 ton of oil per day by natural flow, but elsewhere only traces of oil have been found. At Heath, the nearest to Hardstoft of the other borings, a few ounces of highly filtered oil were met with at the junction of the Limestone Shales and Carboniferous Limestone at 3,950 ft.; slight indications were also found at Ironville II and Ironville I, notably in the latter at 3,630 ft. This 'show' and that at Heath were torpedoed, but no further yield resulted. The top of the Limestone showed no trace of oil at either Brimington or Renishaw, and there is no reason to modify the remarks on the origin and accumulation of the oil made in the 'Summary of Progress for 1919' (pp. 22, 23).

From the purely geological point of view, it will be seen that all the Derbyshire wells have now reached the Carboniferous Limestone; at Ironville I, 1,600 ft. of that formation has been bored through, without reaching the base. Igneous rocks have been encountered in several of the borings; at Brimington, 850 ft. of lavas, with a few thin intercalations of limestone, have

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already been proved. As was expected, both the Lower Coal Measures and Millstone Grits show a steady increase in thickness from south to north.

In Staffordshire, Apedale No. II well was started a few yards distant from No. I well, which was abandoned, the horizon being just above the Bullhurst Coal. At November 9, 1920, the depth was 1,060 ft. in Coal Measures, and the rocks penetrated were sandstones, shales and several coals. At about 1,465 ft. red and green ashy material was entered, approximately at the top of the Millstone Grit, and this continued to a depth of 3,450 ft. (March 23, 1921). This great thickness of volcanic strata was not expected in the bore, as no similar rocks are known to occur near this horizon except at Astbury (Staffordshire) and Ashover in Derbyshire, where they are comparatively thin.

(B)—SCOTLAND.

The field-work in the Highlands has been proceeding in two districts :—

1. West Highland District under Mr. E. B. Bailey, M.C., B.A.
2. North Highland District under Mr. M. Macgregor, M.A., B.Sc.

The coalfield revision was carried on in two districts :—

3. In North Ayrshire under Mr. E. B. Bailey. M.C., B.A.
4. Stirlingshire and Clackmannanshire District, and part of Lanarkshire (Douglas Coalfield), under Mr. M. Macgregor, M.A., B.Sc.

1. West Highland District.

E. B. Bailey, M.C., B.A., District Geologist.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, M.C., B.A.I.
G. V. Wilson, B.Sc.
G. A. Burnett, B.Sc.
} Geologists.

The area surveyed lies mainly in Mull and adjacent islands including Staffa and Iona, Sheets 43 and 51 of the 1-in. Map of Scotland. A commencement has also been made in Ardnamurchan, Sheet 52.

PRE-MESOZOIC ROCKS.

Iona.—The presence in Iona of Lewisian Gneiss, with associated marble, and of sediments strongly recalling the Lower Torridonian of Skye has long been known, and their distribution has been roughly indicated by Sir Archibald Geikie in his ' Geological Map of Scotland ' 1892. Mr. E. M. Anderson adds a new locality for the sediments of Torridonian type, for besides forming a strip along the eastern side of the island, they

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compose Eilean Chalbha and the neighbouring foreshore of the north-western coast.

Undoubted altered sediments within the Archæan complex occur (1) in the neighbourhood of the marble quarry, near the most southerly point of Iona, and (2) to the north of Dun Cul Bhuirg, on the western coast. The quarried marble is an almost vertical band about 20 ft. in thickness, pure white in colour, or white with characteristic greenish streaking. It is associated with other certainly sedimentary material, including a dark graphitic rock, which must be an altered shale.

The sediments to the north of Dun Cul Bhuirg also include bands of marble, one of which has been worked to a very small extent for ornamental purposes, under the name of the 'Silverstone.' It is a pinkish marble, variegated by grains of green serpentinous material, and 'silvery' from the presence of pale-coloured mica, no doubt magnesian. There is also at this locality a broad band of brown biotite-gneiss, very massive and unbanded in its weathered appearance. This passes into a graphite-schist, which is in part pyritous, and is strongly reminiscent of a type found elsewhere in Scottish Archæan sediments.

A period of intrusive activity followed the deposition of these sediments, as is shown by the presence among them of very fine hornblende-schists or epidiorites. They are also cut by coarse unfoliated bands of pegmatite of a type already noted by Mr. Craig in the adjacent island of Soa.[1] As pegmatites are almost entirely absent from the neighbouring sediments of Torridonian facies, their occurrences in the cases just referred to would seem to belong to a late phase of igneous activity of Archæan age, a phase which it is to be noted was later than any period of metamorphism and shearing movements.

Unfoliated pegmatites are everywhere the latest intrusions of the Lewisian complex of Iona, and are by no means confined to areas of undoubted sediments. The basis of the igneous gneiss consists in large part (1) of banded granitic rocks, sometimes containing a certain amount of hornblende in their darker laminæ, and (2) of massive hornblende-gneisses, much coarser in grain than the hornblende-schists already mentioned. The whole formation throughout the island is much veined and irregularly intergrown with epidote. A local concentration of magnetite will be noted on p. 43.

The supposed Torridonian series of the eastern strip in Iona may be roughly divided as follows :—

(2) A younger flaggy group characterised by rapid alternations of more siliceous and more shaly material.

(1) An older group of grits and conglomerates with subordinate shale.

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[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 79.

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A coarse conglomerate can be seen at certain points along the old gneiss margin. The commonest constituents are fragments of granitic rocks evidently derived from the gneiss, and of any size up to two or three feet in length. Boulders of hornblendic rock and of quartz are also occasionally present, as, for instance, at the dividing line of the two formations at the most northerly point on the island. The conglomerate is interbedded with and overlain by pebbly grits, in which the small pebbles consist of quartz and felspar, while the matrix, like that of the conglomerate, is dark grey or dark green in colour. Less commonly, the base is more yellowish green, suggesting epidote. The part of this formation next to the gneiss shows signs of rather intense crushing, perhaps because it acted as a zone of weakness during some period of stress. There is, however, so far as has been observed, no definite break or thrust along the margin. It is important to realise that the crushing referred to above does not introduce uncertainty in the interpretation of the conglomerates. A visit to the wave-washed exposures at the Pigeon's Cave on the south coast is enough to settle this point. There conglomerate layers are interbedded with grits and shaly layers, and one notes that the included fragments differ markedly in character from their surrounding matrix. The crushing manifests itself in the disruption of the bedded series, it does not produce anything approaching a crush-conglomerate.

The later portion of the grits is interbedded with bands of shale, some greenish, others dark and probably carbonaceous, while there is a broad band of dark shale intervening between the last of the grits and the succeeding flags.

The sediments of the north-western coast and Eilean Chalbha are somewhat puzzling in character, but may very possibly represent some part of the conglomeratic group (1) of the east.

The puckering and cleavage which have affected the similar rocks of Colonsay and Islay are almost absent in Iona. Apart from the movement near the margin of the gneiss, these sediments show little sign of dynamic metamorphism. Their bedding is, however, everywhere steeply inclined, E.S.E. in the eastern outcrop, and south-east in the north-western.

The Ross of Mull Granite must underlie a considerable part of the Sound of Iona, as since Macculloch's day it has been known that three small islets close to the Iona shore are composed of granite of the Ross type. It is interesting to note that the band of shale between the grits and the flagstone group has a spotted appearance where it comes near these islets, but not elsewhere. This alteration would seem to prove the post-Torridonian age of the granite, which has hitherto been somewhat in doubt. To avoid confusion, it should be added that Macculloch speaks of an 'appearance of transition' into the granite, but was probably misled by the presence of felspar grains in the flagstone series and also among the grits.

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The unfoliated post-Torridonian intrusions of Iona belong to two classes :—

(1) Basic dykes (apparently basalt and camptonite) run in every azimuth between N. 30° W. and due east and west. Some at least of this group are probably Tertiary, and so do not come under the heading of this section.

(2) The second class includes lamprophyres, which are somewhat irregular but show a marked tendency to follow a series of north and south joint-planes, which dip westwards throughout the island at angles of about 30°. It also includes a group of more acid intrusions, usually pink in colour, and sometimes with basic margins. These occasionally follow the joint-planes referred to, but more often are irregularly rolling with a tendency to horizontality. It is possible that the whole of this class of intrusions are of the same period as a set of mica-traps, granite-porphyries, and porphyrites, found by Messrs. Craig and Bosworth,[1] to cut the Ross of Mull Granite while themselves cut by certain north-westerly dykes. Further evidence of the age of the Ross intrusions will be given presently in the description of Gribun.

Gribun.—Iona has been interpreted by Mr. C. T. Clough[2] as probably a part of the foreland of the Moine Thrust. The thrust itself may be hidden in the Sound of Iona or obliterated by the Ross of Mull Granite; at any rate the well-known gneiss of Erisgeir, Inch Kenneth, and Gribun, with the fuller succession of the Ross, almost certainly belong to the Moine series.

Mr. E. B. Bailey and Mr. G. A. Burnett have found the gneiss just mentioned to be remarkable for its pebbly character. It is a false-bedded arkose-gneiss, retaining much of its sedimentary aspect despite a somewhat high crystallization with a development of garnets in certain micaceous partings.

Two steep sheets of coarse mica-trap have been found by Mr. Bailey on the shore N.W. of Balmeanach traversing the Gribun gneiss and themselves cut off by the unconformable Trias. They dip N.W. and almost certainly belong to the same series as the numerous mica-trap sheets recorded by Mr. Bosworth in 1909 as cutting the Ross of Mull Granite. Thus additional indirect evidence is afforded for Judd's generally accepted view that the Ross Granite is of pre-Mesozoic age.

MESOZOIC ROCKS.

Gribun and Inch Kenneth.—Prof. Judd's classic description supplies the natural datum from which to reckon further advance.

[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 86.
T. O. Bosworth, 'Summary of Progress for 1909.' (*Mem. Geol. Surv.*), 1910, p. 27.

[2] C. T. Clough in 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull.' (*Mem. Geol. Surv.*), 1911, p. 77.

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Prof. Judd[1] recognised Poikilitic, Upper Greensand (Cenomanian), and silicified Chalk. Some years later Mr. J. S. Gardner[2] discovered Lower Lias in the much landslipped Wilderness (north and south of Aird na h-Iolaire), and corrected Judd's mistaken impression that Greensand is to be found in Inch Kenneth. In addition, Gardner questioned whether Judd's 'Chalk' was *in situ*, for he thought it all *remanié* in Tertiary deposits, but in this he went too far, as may be seen for instance in Allt na Teangaidh, just below the main road.

The results of last year's work may now be briefly stated. The various groups were mapped by Mr. Bailey, the main exposures were measured by Mr. W. Manson, who collected 750 fossils, and the examination of these has been started by Dr. G. W. Lee.

Judd's Poikilitic—or Trias, as one is justified in calling it—is some 200 ft. thick at Inch Kenneth, where the gneiss floor disappears below the sea, and about 10 ft. thick 2½ miles farther south where gneiss rises 700 ft. in the coastal cliffs of Mull. An unrecorded feature is the abundance of pebbles of red Torridon arkose and fine grained (? Durness) limestone. Some of these far-travelled limestone pebbles are enclosed in an envelope of chert.

For about 2½ miles along its outcrop the Trias is succeeded by definite Rhaetic. The prevalent type is dark sandy limestone, or calcareous sandstone, with rather wavy bedding and no trace of concretionary structure. Lamellibranchs are numerous. The best section is in Allt na Teangaidh near Balmeanach, where about 30 ft. are laid bare. The fossils include *Pteria contorta* [*Avicula*], *Gervillia præcursor*, and *Pecten valoniensis*. This is the second record from Scotland of demonstrable Rhaetic beds—the only occurrence known hitherto is the mass of shale found by Messrs. Peach and Gunn tumbled down the throat of a Tertiary volcano in Arran.

In the Wilderness the Trias is succeeded in a low cliff south of Uamh nan Calman by shales and cement-stones. Although the section suggests continuous deposit there is nothing of the type of the Balmeanach Rhaetic—no fossils could be found, but the facies of the shales and argillaceous limestones is distinctly Liassic. What follows is confused by landslipping, but in small cliffs south of Aird na h-Iolaire the lower part of the Hettangian is very definitely represented, and in associated loose blocks one finds a Sinemurian fauna. Taken together these correspond with the Broadford Beds of Skye.

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[1] J. W. Judd, 'The Secondary Rocks of Scotland.' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, pp. 694, 732. See also a critical discussion of the unconformity at the base of the Gribun Secondaries, J. Macculloch, 'Western Islands of Scotland,' vol. i, 1819, p. 563.

[2] J. S. Gardner, 'Leaf Beds and Gravels of Ardtun, Carsaig, etc. in Mull.' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 284.

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The Hettangian of the cliff section is divisible into two :—

(*a*) One ft. red mudstone, overlain by 19 ft. mostly micaceous calcareous sandstone, 8 ft. sandy limestone and calcareous shale crowded with *Ostrea liassica*, overlain by

(*b*) Twenty ft. shales and limestone assignable to the Planorbis Zone.

The Oyster Bed facies, characterising the upper part of (*a*), is well known in the lower Hettangian of England and again in Skye, but not elsewhere in Mull. The *planorbis* fauna of the lower Hettangian has never hitherto been forthcoming in Scotland, though carefully searched for.

The Sinemurian fauna has been found, as already stated, in loose blocks. One may mention *Lima gigantea* indicating the lower part of the Sinemurian, and typical *Gryphaea arcuata*, also betokening Sinemurian but not necessarily its lower stages.

Prof. Judd, the original discoverer of Cretaceous rocks in Scotland, emphasized the bearing of his observations upon Suess's generalisation regarding the Upper Cretaceous transgression of the European area (*op. cit.*, p. 683). For instance, in the Gribun peninsula nothing remains between the Lower Lias and the Cenomanian.

Dr. G. W. Lee, some years ago, justified Judd's employment of the name Cenomanian for the Greensand of Mull by finding a zonal ammonite near Loch Don. The best Gribun exposure is below the road in a great landslip N.E. of Balmeanach. Oyster banks with *Exogyra conica* and occasional *Serpula* are very conspicuous. Additional fossils to those recorded by Judd are : *Pecten orbicularis* and *Pecten asper* (?). Judd's *Spongia paradoxica* is probably based on highly characteristic sandcasts, and Mr. Bailey points out that these resemble forms common in the Upper Greensand of Eastbourne for which Mr. Clement Reid[1] has offered a very different interpretation.

The Greensand of Gribun may be taken as about 20 ft. thick. Above follow white sandstone 10 ft. and Chalk 10 ft. The white sandstone has not previously been described from Gribun, but it is in keeping with Judd's general sequence.

Ardnamurchan.—Mr. J. E. Richey commenced the examination of the Ardnamurchan Secondaries. In the cliff west of Sron Bheag, the southernmost point west of Kilchoan, there is a mass of baked sedimentary rock which is probably Inferior Oolite. It is about fifty feet thick and has a distinct resemblance to Chalk; the exposure is rather inaccessible and has not yet been fully examined.

TERTIARY SEDIMENTS IN MULL.

Mr. Bailey has found that the silicified chalk of Gribun is veined by sandstone, and that in places (*e.g.*, Allt na Teangaidh) similar sandstone constitutes a thin overlying bed. This sandstone shows marked wind-rounding of its grains, and may, there-

[1] Clement Reid, 'The Geology of Eastbourne.' (*Mem. Geol. Surv.*), 1898, p. 5.

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fore, be claimed as a desert deposit. Another interesting point is that the silicification of the chalk is of later date than the desert sand. An extension of the chert which replaces the chalk in many cases serves as matrix to the grains of sand. Elsewhere it is commonly found that the grains have added fresh crystal facets, and thus lost much of their rounded outline.

To investigate the extent of this Tertiary desert sand, a visit was made to the Tertiary sandstone of Carsaig. Wind-rounding was here again very evident, and included fragments of silicified chalk were seen surrounded by a halo of chert serving as a local matrix for the adjacent sand-grains.

In Allt na Teangaidh the desert sand is overlain by the thin, red mudstone so often met with at the base of the Mull lavas. This deposit, and the somewhat later leaf-beds and coal-seams, obviously indicate a change of climate.

TERTIARY LAVAS.

Local discordance, Bloody Bay, Tobermory.—A general feature of the Mull lavas is the even way in which they follow a thin layer of Tertiary sediments which in turn rests with misleading conformity on underlying Mesozoic rocks. Mr. G. V. Wilson has found a most unusual appearance presented in an old sandstone quarry in the sea cliff of Bloody Bay. The locality is about 1¼ miles S.E. of Ardmore Farm and of easy access from above, or by boat from Tobermory. Prof. Judd, speaking of the sandstone, justly remarks: "the eroded surfaces of these beds is seen to be directly covered by the . . . basaltic lavas" (*op. cit.*, p. 715). The most interesting feature of the exposure is the peculiar way in which the flat-bedded sandstone juts up as a knob into the overlying lavas (Fig. 1). Along

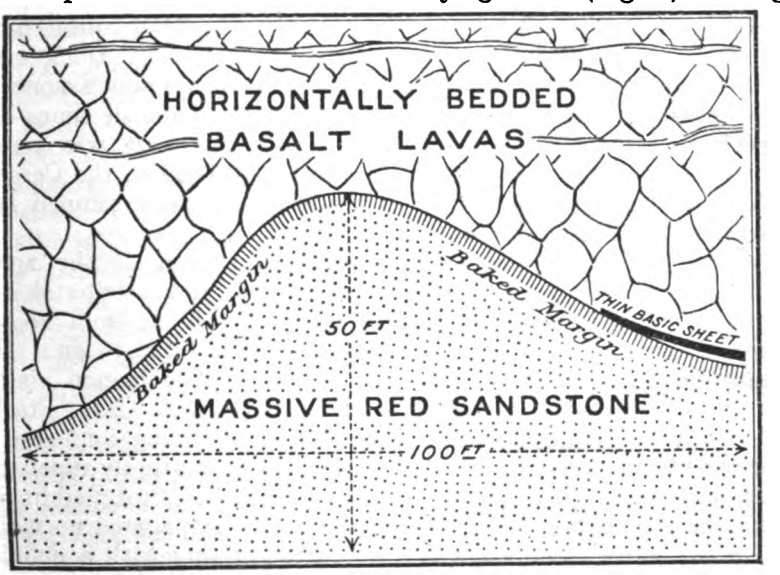

FIG. 1.—Tertiary lavas overlying a weathered knob of sandstone at Bloody Bay.

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the line of contact the sandstone shows a baked zone which extends inwards for several inches.

The sandstone is of good quality and has been used in the wall of the path leading to Rudha nan Gall Lighthouse. It is at least 50 ft. thick, current-bedded and red in colour, with a small proportion of rounded grains. It also carries irregular concretionary bands of iron-ore. The outcrop can be traced for about 200 yds. and is terminated in both directions by what appears to be a fault running almost parallel with the cliffs and bringing basalt lavas down to sea-level. The age of the sandstone remains doubtful.

Columnar Lavas, Staffa and elsewhere.—The cliffs of Gribun have enabled Mr. Bailey to realise that the columnar lavas there seen all occupy a very low position in the Plateau Lava group of Mull. Comparison with other districts is rendered somewhat unsatisfactory, as columnar structure is often poorly displayed in ordinary inland exposures, but it seems certain that all the columnar lavas of Mull are of relatively early date. They have a geographical as well as a time limit. They reach their fullest development where mapped by Mr. Anderson in the cliffs west of Carsaig, whence they continue by Ardtun into the Gribun peninsula, Ulva and Staffa. Reidh Eilean, outside Iona, has yielded Mr. Anderson a hitherto unrecorded occurrence of columnar structure of spectacular type, but the columnar rock in this case is of unusually doleritic texture, and its field relations are hidden by the sea. The only columnar lava not falling within the south-west corner of the Mull district is an example noted by Mr. Wilson towards the base of the series at Bloody Bay, near Tobermory.

A feature of a large proportion of the columnar lavas of the Mull area is their triple-zoned appearance. They often have a thick slaggy top merging down into an equally thick zone of narrow wavy columns, which rests in turn upon a zone of more massive vertical columns. This combination of zones has received little attention in previous writings, but was noted some years ago by Mr. Anderson and Mr. Wilson in the Carsaig cliffs. It is nowhere better seen than in Staffa, examined last year by Mr. G. A. Burnett.

Prof. Iddings gives a very useful discussion of the zonal jointing of analogous American examples, and attributes the upper zone of columns to irregular rapid cooling from above, and the lower zone to regular slow-cooling from below. His interpretation accounts for a very striking phenomenon visible on the foreshore a little north of the Clamshell Cave, Staffa. Here the two systems of joints, instead of becoming confluent at their contact, as is often the case, seem to be mutually repellant, for they suddenly swing into parallelism. Prof. Iddings'[1] explanation is that the jointing tends to be propagated normally to a retreating isothermal surface corresponding with a definite

[1] J. P. Iddings, 'Igneous Rocks,' vol. i, 1909, figs. 13, 15, 16, p. 322.

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temperature, and that when cooling from above and below brings two such surfaces together the form of the combined surfaces is materially modified by a rounding off of the angle of contact—from which follows a corresponding deflection of the developing joint-planes. On the other hand, the commonly observed confluence of the two sets of joints is, of course, to be interpreted as evidence of the influence which two approaching joint systems may exercise upon one another, and is not to be taken as a contradiction of Prof. Iddings' explanation.

The two columnar zones of the Fingal's Cave lava of Staffa are among the most familiar of geological phenomena, though they have been previously ascribed to independent flows in Sir A. Geikie's descriptions. Mr. Burnett has shown their true relationship. He has also found that the northern half of the traverse between Clamshell Cave and Goat Cave affords an excellent coast section of the top zone of the Fingal's Cave lava consisting of commingled slag and solid, merging finally to pure slag. In the mixed part of this uppermost zone early masses of slag have clearly been involved in, and carried forward by, still liquid portions of the flow, the latter now represented by columnar basalt. At Goat Cave the slaggy top of the Fingal's Cave lava is covered by a few feet of carbonaceous and ashy sediment, which in turn is overlain by further basaltic flows constituting Meall an Fulann.

It has long been known that the Fingal's Cave lava is underlain by red ash. A convenient exposure can be reached from above at Port an Fhasgaidh. The massive columns here reach down to about a foot from the ash, but the bottom layer of the lava is brecciated and vesicular. A 1-ft. sill of basalt, chilled at top and bottom and clearly transgressive, lies just a little below the lava base.

The Fossil Tree of Burgh.—Another famous columnar lava of the district is that which flowed round and over the fossil tree of Burgh—to use a now familiar name. The cast of this tree trunk stands in a recess of the coastal cliff of the Gribun peninsula, 150 yds. north of the waterfall of Allt Airidh nan Caisteal. Geologically speaking it is the most wonderful spectacle in all Mull, and like so much else of interest in the west of Scotland, was made known over 100 years ago by Macculloch. Sir Archibald Geikie has published a photograph in his Text Book of Geology (1903, p. 758). The cast of the tree is seen in vertical section, and looks like a pipe, nearly 5 ft. broad and about 40 ft. high, and largely filled with breccia consisting of lumps of 'white trap' and charred wood. The lower part of the pipe encloses a partially silicified semi-cylinder of wood glittering with quartz crystals. The diameter of the cylinder is about 3 ft., and outside is a hollow where soft black coniferous wood, a couple of inches thick, may be dug out with a hammer. In Macculloch's day the wood continued as a coat around the silicified cylinder, but since then has been ruthlessly stripped away by curio-hunters.

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The pipe rises in the heart of a columnar basalt, and the columns as they approach it turn so as to meet it everywhere at right angles. Geikie and Gardner have described the pipe as reaching right up through one lava and overlain by another, but such is not the case. Macculloch seems to have thought that the tree had somehow found its way into a fissure of the basalt.

A prostrate tree is included in a brecciated portion of the same lava exposed in a cave 230 yds. north of the upstanding tree. It is probable, Mr. Bailey says, that these two trees are mere remnants of a forest. At any rate the lower part of the lava in this neighbourhood has very unusual characteristics. It rests regularly on a thin carbonaceous layer following an important ash, but within itself it is wonderfully irregular. It consists, in fact, of a chaotic assemblage of columnar and more or less brecciated vesicular basalt. The columnar basalt traverses the brecciated, or sweeps round great masses of it 40 or 50 ft. high. Everywhere the columns are at right angles to the line of contact, no doubt because the slaggy breccia could offer practically no resistance to contractional force during cooling. The columnar basalt sometimes comes in contact with the underlying carbonaceous mud, and is distinctly chilled, as has been found to be the case with a few other lava bases in Mull; but it is unchilled where it joins the breccia.

The lava is unusually thick, and the irregularity of its basal part may be looked upon as a special feature. Apart from this it exhibits the triple zoning already mentioned as characteristic of the Fingal's Cave lava, etc.

Flow-Banding and Pipe Amygdales.—A curious type of flow-banded lava has been met with in many parts of the district surveyed last year, more particularly in Gometra mapped by Mr. Burnett; the banding is often sufficiently lenticular to remind one of pillow structure, but the lenticles are, on the whole, much too elongated to be called pillows, and they are not defined by noticeably chilled margins. Each band has typically three layers, a basal zone with pipe-amygdales, a middle solid zone, an upper zone with crowded little rounded amygdales. There is a distinct separation of the bands, for nowhere can one point to round vesicles of the top of one band extending up among the pipes of the next. Mr. Richey has found a section at the roadside 350 yds. E. of Kilninian Church, which throws considerable light upon the conditions attending the formation of this banding. Reddening such as is commonly attributed to surface weathering during the volcanic period, extends along the junction lines of the successive bands; this seems to point conclusively to an imperfect contact of the bands, so that it is fair to regard the banding as a surface phenomenon resulting from successive overflows upon the surface of a parent lava.

Pegmatitic Veins.—Several examples of contemporaneous pegmatitic linings to vesicles, and of associated veins, have been encountered this year in basaltic lava flows. Mr. Bailey had

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previously noted the phenomenon on the shores of the sound of Mull, and Dr. McLintock[1] has described it from the Ben More district. The interest of the recent finds is their occurrence outside the area of pneumatolysis of central and eastern Mull. The pegmatitic veins, where, for instance, they have been found by Mr. Burnett in Gometra, are seen stringing basalt lavas which still carry their olivine in large measure unaltered.

Ben More Mugearite.—Sir A. Geikie,[2] in separating a pale group of Mull lavas forming the upper portion of Ben More, spoke of the occurrence among them of trachytic flows. During the survey of the district it was thought that Geikie's trachytic flows were really a great mugearite sill, and this statement has been published. On the other hand, Mr. Wilson, in the Loch Buie district, definitely recognised as lavas certain mugearites which evidently occupied much the same stratigraphical position as the mugearite of Ben More. Accordingly, Mr. Bailey investigated the matter last season, and states that the continuation of the Ben More mugearite south of Kinlochscridain can be shown to be a lava with a weathered, slaggy top. In keeping with this, Mr. Richey has found a thin sedimentary layer, immediately above the mugearite in Ben More itself, containing numerous fragments of mugearitic type. Moreover, the section which led to the view that the mugearite was intrusive, when examined this year by Mr. Bailey and Mr. Anderson, proved to be misleading.

TERTIARY INTRUSIONS.

Mull Sills.—Messrs. Bailey and Anderson have completed the mapping of the Loch Scridain area of sill-intrusion, and Mr. Wilson has found and mapped a distinct area in the northern end of the island. In both cases the sills are very transgressive.

Among the noteworthy features of the Loch Scridain sills are :—

(1) frequent residuum of pitchstone,
(2) numberless highly altered xenoliths,
(3) occasional and local absence of chilled margins.

(1) and (2) of the above have often been described already. Mr. Bailey has now found instances combining all three characteristics, as, for instance, at Scobull Point, Loch Scridain. Messrs. Anderson and Radley[3] have pointed to the pitchstone residuum as evidence of retarded crystallization, and have argued that it has been determined by an unusually high water-content in the magma supplying the sills. Mr. Bailey points

[1] W. F. P. McLintock, 'On the Zeolites and Associated Minerals from the Tertiary lavas around Ben More, Mull.' *Trans. Roy. Soc. Edin.*, vol. li, 1917, pp. 15, 18, 21.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, p. 214.

[3] E. M. Anderson and E. G. Radley, 'The Pitchstones of Mull and their Genesis.' *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, p. 205.

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out that the characteristics (2) and (3) suggest retarded consolidation in contact with cold surfaces, not by any means the same phenomenon as retarded crystallization, but very likely attributable to the same cause.

Mull Dykes.—The belt of N.W. dykes belonging to Mull is about 10 miles broad. Mr. Wilson has found that the topography of northern Mull, within the belt, is lineated N.W. and S.E., in striking contrast to that of adjacent districts.

Ardnamurchan Complex.—In a preliminary investigation of the Ardnamurchan peninsula, Mr. Richey has confirmed Dr. Harker's[1] announcement of a well-defined belt of centrally inclined basic sheets (cone-sheets). The sheets dip to a common centre, which is situated approximately beneath Beinn na h-Imeilte, between Sanna Bay and Kilchoan. The belt can be traced round half the circumference of a circle, extending from Faskadale on the north side of the peninsula to the south-west side of An Acairseid. It is at any rate three miles in annular width. The sheets composing the outer half of the belt are individually the more massive, and attain unique development on Ben Hiant,[2] where single members are upwards of 100 ft. thick. The dip also varies, becoming gentler towards the exterior of the belt, as, for example, in the Ben Hiant district.

The great gabbro mass, long known to form the western part of the peninsula, has a steep or vertical junction, which follows closely the strike of the belt of cone-sheets. It is considered to be later than the sheets for the following reasons :—

(1) The gabbro is free from the sheets, whereas the sheets occur in great force immediately outside it.

(2) The sheets, together with their country rock, become increasingly altered by thermal metamorphism towards the gabbro junction.

(3) An isolated area of basalt lava traversed by sheets, presumably belonging to the set of cone-sheets, was observed surrounded by gabbro on Meall an Tarmachain.

PREGLACIAL MARINE EROSION.

The district includes many evidences of Preglacial marine erosion at about 100 ft. above sea level, already described by Mr. Wright,[3] whose conclusions have been confirmed. Of cognate interest is an old sea cave at a higher level, to which Mr. Burnett's attention was directed by Mrs. Clark of Ulva. It opens on the south-east slope of A'Chrannag, Ulva, and its floor, where reached in a trench, lay 150 ft. above high-water mark. It measures

[1] A. Harker, 'Anniversary Address of the President.' *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1917, part 1, p. xciv.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, pp. 318–322.

[3] W. B. Wright, 'Preglacial Shoreline in the Western Isles of Scotland.' *Geol. Mag.*, 1911, p. 97.

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40 ft. broad, 50 ft. deep, 25 ft. high, and its bottom is covered with a deposit of boulder-clay up to 5 ft. thick, charged with granite, gneiss, and Liassic limestone derived from Morvern and the Sound of Mull. The far-travelled erratics are, taken together, much more numerous than basalts such as might have come from the island itself. The level corresponds with that of a well-marked, though heavily glaciated, shoreline found some years ago by Mr. Anderson at the head of Loch Scridain.

ECONOMICS.

Iron Ore, Iona.—Magnetic iron ore was known to have been found near the southern end of Iona. Mr. E. M. Anderson reports its occurrence at two localities :—

(*a*) Close to the shore directly north of the eastern end of Eilean Musimul. The material here forms a vertical band from 2 ft. to 4 ft. in width, traceable for about 200 ft., and running parallel to the banding of the adjoining gneiss. The magnetite is mixed with garnet and other impurities, but the state of concentration is, perhaps, rather greater than that of the next locality.

(*b*) Close to the shore just west of Port an Fhir-bhreige (the western part of St. Columba's Bay). There is here a zone of impregnation some 10 or 15 yards in width, which can be traced for nearly 100 yards; but the deposit is most irregular, and only a small part of this thickness can be classed as even inferior ore.

Until assays of the material have been made, it is not possible to estimate the amount of iron, and it is likely that the limited nature of the deposits so far apparent would prevent them from being profitably workable.

Marble, Iona.—The well-known Iona marble quarry has not resumed working since the war. The stone was used for interior decoration, especially in churches. The available reserves are not sufficient to allow the development of the industry on a large scale, but would probably meet a limited demand for many years to come.

Sandstone, Bloody Bay, Mull.—Attention may be directed to the sandstone of Bloody Bay, described on p. 38. It has already been quarried for the Rudha nan Gall lighthouse, and is a serviceable stone on the water's brink should building material be again required in this locality.

Lime, Mull.—The white sands of Calgary Bay could supply an inexhaustible supply of lime. Mr. Wilson reports rather more than 70 per cent. of $CaCO_3$ in a type sample.

The cornstones at the entrance of Loch na Keal might perhaps be used for local purposes. The most favourable outcrop is that of the sea-cliff below Inch Kenneth Chapel.

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2. North Highland District.

M. Macgregor, M.A., B.Sc., District Geologist.
C. H. Dinham, B.A.
H. H. Read, B.Sc., A.R.C.S. } Geologists.
D. Haldane

Field-work was resumed during the past season in the North Highland District, and considerable progress made with the survey of One-inch Sheet 102. The ground surveyed lies in the south-eastern quarter of the sheet, partly in Sutherland, partly in Easter Ross.

EASTER ROSS.

In the Ross-shire ground, Mr. Dinham surveyed an area lying north of the lower part of Strath Carron. The greater part of this tract is covered by morainic drift, and the rocks, which are found only in the stream sections and along the shores of the Kyle of Sutherland, consist of the usual siliceous granulites of Moine type, with thin and rare pelitic bands, scarce sills of chloritic and garnetiferous hornblende-schist, and lamprophyres of two types, distinguished by brown and brick-red weathering. Near Culrain, where the Kyle first narrows, the top of Lamentation Hill (Creag a' Choineachan) and the ground to the west of it are comparatively free from drift. At the very summit of this hill outcrops a brown-weathering lamprophyre, with abundant well-rounded inclusions of schist and of a pink granite. The contrast between the resistance of this tough, scarcely jointed rock to the action of ice, indicated by its tendency to occur in rock knobs, and its easy susceptibility to ordinary atmospheric weathering, is well illustrated here. This dyke has been traced at intervals for at least 1,000 yds. to the W.N.W.; in the opposite direction it is probably continuous, though the connection is not visible, with the exactly similar dyke of Sithean Mor across the Kyle (p. 47).

The 50-ft. Raised Beach forms a well-marked flat here and there on the west shore of the Kyle. At the lower end of Strath Carron the sands and gravels of this beach must have constituted a delta, the greater part of which was situated below the level of tidal waters, while the higher layers, and the part which lay furthest upstream, were fresh-water deposits at the mouth of the Carron; similarly with the present-day river, the delta, formed partly at the expense of the earlier one, lies on the average two or three feet above high-water mark, and the tides do not penetrate more than a quarter of a mile upstream from the river mouth, so that the highest layers of the delta are properly fresh-water deposits. The 50-ft. beach rises to 62 ft. about a third of a mile east of the railway, but beyond this point the surface becomes broken and the beach merges into a tract of irregular gravel mounds, separated by hollows without outlet, indicating the proximity of the tongue of a valley glacier.

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South of the viaduct across the Kyle at Culrain the 50-ft. beach must have been chiefly formed out of materials brought by marginal and other streams, and deposited here at the foot of the Oykell Valley glacier. The fluvioglacial origin is also indicated by the presence of two or three kettle-holes, close to Culrain Station, in the otherwise flat-topped beach. Before the sea sank below the 50-ft. level, the ice had retreated at least as far as Inveran, for the raised beach, though mostly forming a narrow fringe with broader expanses near Inverhouse, still makes a well-defined flat, with a large kettle-hole near the sharp bend of the road east of Rheantaoir. West of this, however, the terrace breaks up into hollows and mounds, the latter not rising higher than the level of the beach until beyond Rhelonie, where all trace of the terrace feature finally disappears.

There is some indication of a glacial overflow channel which, entering the wood south of Rheantaoir just below the 100-ft. contour, utilised and partly deepened the gorge leading eastwards to Inverhouse. The broad spread of 50-ft. beach at this point, already referred to, may be largely formed out of materials brought through this channel into tidal waters, at a time when the ice-foot lay between Inveran and Rheantaoir.

SUTHERLAND.

Messrs. Read and Haldane report that in the ground surveyed by them between the Kyle of Sutherland and Strath Fleet, the country rock consists of siliceous granulites in which occur granite masses and subordinate igneous rocks of various kinds.

Schists.—In type, the Moine rocks are very uniform throughout; they are white or pinkish siliceous granulites, in which what appear to be relics of felspar pebbles are occasionally seen. Narrow bands of a semi-pelitic nature are of rare occurrence. At a few places, lenses and small bosses of dark hornblendic rock have been found. These are usually schistose, but are occasionally rather massive, and are presumably of igneous origin. Throughout its extent, the siliceous granulite is traversed by great numbers of acid stringers, veins, and small dykes, which form intricate complexes. About a mile S.W. of Achany Lodge a prominent knoll, consisting of white vein quartz much crushed and broken, rises out of the surrounding peat flat; a similar smaller knoll occurs some distance to the south-east.

Granites.—In the Migdale area and northwards by Loch a' Ghobhair and Loch an Lagain, Mr. Read has mapped a large mass of granite, which forms the crags of Migdale Rock, Craig a' Bhealaich and Creag a' Ghobhair, and covers an area of about six square miles. It is a non-foliated, fine-grained whitish rock with a small amount of biotite. On Migdale Rock, the granite is traversed by numerous contemporaneous pegmatites of an average width of 1 in. These seem to have been formed by exudation of the last juices of the granite magma into early

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joint planes in the already solid normal rock. The direction of the joints is N. 10 E—S. 10 W. Later still seem to be narrow quartz veins which run N. 10 W.—S. 10 E.; these later veins have occasionally pegmatite at their margins and quartz at their centres.

On its western and southern margins the Migdale Granite has a sharp junction with the Moine granulites; the granite is welded to the foliation planes of the granulite, which is little altered, possibly because it had already reached so high a degree of mineral stability. On the eastern and northern margin, however, no definite line can be drawn for the junction, for here a thorough complex of granite apophyses and granulite is found, which forms a belt half a mile or so in width outside the solid granite.

At Beinn Donuill, 5 miles N.E. of Bonar Bridge, a basic margin to the granite is seen. In parts the basic mass is composed of a very coarse black hornblende-biotite-rock of a scyelitic nature; with this are associated hornblende-biotite-rocks with patches of pink felspar; other types show approaches to granite. There is here little doubt that the scyelite and associated hybrid rocks belong to the Migdale Granite intrusion. The importance of this fact will be seen immediately in the discussion of the Ach'uaine hybrid rocks.

Part of the Lairg-Rogart Granite falls within the area surveyed. Mr. Haldane notes that in the Fleet valley the rock is an unfoliated coarse-textured biotite-granite, with occasional patches of dark basic material. This granite passes eastwards into the somewhat paler type seen at Dalmore.[1] This intrusion is separated from the Moine granulites by a well-marked belt of crush with a N.W.—S.E. direction which has determined the course of the Fleet valley at Acheille.

Rocks probably of hybrid origin.—At Ach'uaine (Gælic—green field), 2½ miles N.N.E. of Bonar Bridge, the vivid green herbage of the fields makes a striking contrast to the heather-clad ground occupied by the siliceous granulites and Migdale Granite. On examination, Mr. Read finds this to be due to the occurrence of ultrabasic and associated rocks at this locality. These rocks form a series of detached, elongated, irregular masses on the ground around Ach'uaine and Ledsaurich. They have also been met with further north around Cnoc a' Choire Bhuidhe by Mr. Haldane. From Ach'uaine a broken belt runs north for nearly a mile to Asdale. Near Ledsaurich another belt runs for about a mile with an average width of 100 yds.

Until a thorough microscopic examination of these rocks has been made, little beyond the impressions formed in the field can be given. The rocks of these basic masses are regarded as mixed rocks formed from two types, an ultrabasic scyelite type and a granite type resembling the Migdale granite. The

[1] *Vide* 'Summary of Progress for 1909' (*Mem. Geol. Surv.*), 1910, p. 41.

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scyelite is a hornblende-biotite-rock with large plates of black mica often 2 cms. across; the granite is a pinkish very fine-grained rock with scarce and small biotites. It is considered that, by the mixture of these two types, sometimes as magmas, sometimes by incorporation of ultrabasic in acid magma, sometimes by penetration of almost solid ultrabasic material by acid magma, there have been produced the innumerable varieties of mixed rocks seen in these masses. Some of these mixed types are :—

(1) Hornblende-biotite-rock with large patches of pink felspar.

(2) Finer grained rocks of similar composition to (1).

(3) Streaky rocks formed by inclusion of hornblende-biotite-rock in a granite base.

(4) Purplish 'acidic' types with large plates of biotite.

(5) Innumerable mixtures formed by the intrusion of granite into scyelite without assimilation.

Mr. Dinham has found what appear to be rocks related to those just described at a locality 150 yds. south of the top of Lamentation Hill in Ross-shire.

Lamprophyres.—Mr. Haldane has recorded a lamprophyre dyke on the summit of Sithean Mor, 1 mile east of Invershin. This dyke trends almost due east-and-west and can be traced for over a quarter of a mile, and is possibly the continuation of that noted by Mr. Dinham on Lamentation Hill in Ross-shire (*see* above, p. 44). It cannot be traced far east of Sithean Mor. It is a quite unfoliated dark massive rock with abundant large plates of black mica. It contains many inclusions of Moine granulite and of granite (Migdale Granite?), which stand out as knobs on the weathered surfaces. Similar lamprophyre dykes have been found by Mr. Read at Creagan Reamhar, Garbh Leathad, Allt na Feith Moire and Allt na h' Atha. That these lamprophyres are later than the Migdale Granite has been proved by Mr. Read's discovery of a lamprophyre dyke cutting the granite at Loch Leisgin.

Old Red Sandstone.—At the eastern edge of Sheet 102 and south of Strath Fleet a small faulted-in patch of flaggy red sandstone has been noted by Mr. Haldane. Granite occurs both to the north and to the south of this patch but no actual boundaries are seen. The sandstone dips at 30° to the south-east, and is probably the termination of the Old Red Sandstone belt shown in Sheet 103, which may be here cut out by the large N.W.–S.E. fault already mentioned as occurring in the Fleet valley.

Pleistocene and Recent.—On the north-east shore of the Kyle of Sutherland, between Bonar Bridge and Linsidemore, there is a well-marked 50-ft. beach which, when traced up the Oykell valley, displays features similar to those described above by

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Mr. Dinham for the beach on the south-west side of the Kyle. There are also traces of a lower shelf at about 25 ft.

Coalfield Revision.

3. North Ayrshire Coalfield.

Field-work was mainly carried on in the volcanic district of Sheet 22. Mr. Anderson was engaged in the completion of coalfield maps commenced by the late Mr. C. T. Clough and himself. A boring for coal was visited near Rankinstone, and replies were furnished to enquiries from colliery managers entailing field observations in the Troon and Dalmellington districts.

The revision of the Calciferous lavas of the Clyde plateau has been continued by Mr. Richey and Mr. Burnett in the hill country between Stewarton and Mearns. Chief interest centres in a great spread of trachytes,[1] of which 8 square miles have now been mapped. It is probable that most of these trachytes are lava flows, though this conclusion is based on somewhat sparse observation of vesicular tops, unchilled margins, and intercalated beds of tuff. The stratigraphy of the area is especially difficult to work out, as the country is of low relief, with scarp-featuring ill developed; added to this there is extensive faulting and also an original discontinuity of the various lava zones, some of which were referred to in last year's 'Summary of Progress.' It can, however, be definitely stated that the widespread top Dalmeny Group of last year's classification continues eastwards through the uplands north of Fenwick, and is underlain by trachytes, to some extent associated with mugearite and various types of basalt, and that this assemblage is in turn underlain by a thick group of macroporphyritic basalt lavas. Considerable areas of trachyte occurring to the east of the Mearns–Fenwick road appear to be overlying the continuation of what is elsewhere the top group of Dalmeny basalts, but their mapping is incomplete. In this connection it may be mentioned that evidence of an acid phase posterior to the Dalmeny Group is afforded in other parts of North Ayrshire by the occurrence of abundant felsitic pebbles in the volcanic detrital beds that form the base of the Calciferous Sandstone sediments overlying the lavas.

4. Stirlingshire and Clackmannanshire.

The revision of the Stirling and Clackmannan area of Carboniferous rocks was continued during the spring and autumn by Messrs. Dinham, Read and Haldane, and that of the Douglas area by Mr. Macgregor. In addition to the normal field work short visits were paid to different localities in connection with

[1] J. E. Richey, 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 27.

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various 6-in. maps of the Central coalfield in course of publication. Borings for coal and ironstone in the districts of Barrhead, Glasgow, Airth, Bo'ness and Douglas were also examined during the course of the year.

STIRLINGSHIRE.

Mr. Dinham, in continuation of his work on the Lower Limestones on the north side of the Central coalfield,[1] began a re-examination of certain critical sections in the Corrie Burn district in 1-in. Sheet 31. The discovery in the middle burn of a representative of the "sandy encrinital limestone of Campsie," which occurs between the Hurlet and the Blackhall Limestones, is worth recording. This bed had previously been discovered in the Shields and Bannock burns,[2] but had not been recognised at Corrie, which lies between them, doubtless owing to the fact that the limestone is everywhere decalcified and resembles an ochreous sandstone. Its position in the Corrie sequence is shown in the following table :—

	Ft.	in.
Gap	—	—
Sandy LIMESTONE with occasional encrinites, &c.; the bottom 15 in. consists of thin beds very full of various marine fossils. Thickness apparently about	6	—
Gap about	5	—
Faky blaes	1	—
Sandstone, flaggy false-bedded	1	6
Sandstone, thin bedded and colour-striped	2	—
Gap	5	—
HURLET LIMESTONE seen here	7	—

The decalcified limestone is seen again 100 ft. further to S.W., at the east corner of an old quarry in the Hurlet Limestone.

In 1-in. Sheet 39 Mr. Dinham was engaged on the survey of the ground lying south and east of Stirling. The chief points of interest in the surface geology are :—

(i) The discovery at Craig Moss, 3 miles S.E. of the town, of a hitherto unmapped 'islet' of rock in the middle of the Carse flats. (ii) The presence of large erratics of Highland grits of Ben Ledi type, and of Old Red Sandstone conglomerate, on the slopes of Dunmore Hill. (iii) The tracing of the old coast line of the '100-ft.' raised beach. The inner margin of this beach appears to rise to at least 145 ft. above O.D., and is fringed by terraces of sand and gravel which at Cambusbarron attain a thickness of at least 50 ft. Around Carnock and Castleton the old coast line crosses the outcrop of the massive sandstones of the Millstone Grit. These now form conspicuous lines of crags

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, pp. 34-41.
[2] *Ibid.*, p. 38.

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—a phenomenon rare in the Millstone Grit of Scotland, and due in this instance to the removal of the usual boulder-clay cover by the waves of the old sea, on whose shore they projected as rocky reefs and islands. The sudden disappearance of these crags as the old coast line is followed towards the north-west, coincides with an abrupt passage, across a large fault, from Millstone Grit into strata of the Upper Limestone Group, in which sandstones are neither as thick nor as numerous. This fault has also been approached from the north side in the workings of Carnock Pits; its throw amounts to at least 200 fms., and it is probably a continuation of the big Campsie Fault, which separates the coalfields of South Stirlingshire from the lavas of the Kilsyth Hills.

CLACKMANNANSHIRE.

Coal Measures and Millstone Grit.

Mr. Read has begun the revision of the Alva, Menstrie and Alloa districts of the Clackmannanshire coalfield. A general section of this coalfield is given in one of the published sheets of vertical sections (Sect. 4, Sheet 5, Scotland, 1877). It illustrates the ground immediately adjoining Devon Ironworks (now Devon Colliery) about 1 mile south-east of Alva, and shows at the top 72 ft. of red sandstone assigned to the Barren Red Measures. These beds are seen in the quarries around Devon Colliery, in the railway cutting near Black Row, and probably also in the Silver Glen, 500 yds. east of Alva Church. They are coarse reddish false-bedded sandstones and occupy the centre of the northernmost basin of the Clackmannan field. Their correlation with the Barren Red Measures is still open to doubt since sandstones of very similar type occur in this district within the limits of the Productive Coal Measures.

Abandoned shafts of which no records exist are very common in the Clackmannanshire field, coals and ironstones, both clayband and blackband, having been wrought here from an early period. Some of the workings must be at least 125 years old; the clayband ribs above the Nine-Foot coal, for example, were mined for the long-abandoned Devon Ironworks (*circa* 1792–1856).

The Devon basin is limited on the north by the Ochil Fault. Good sections are seen in the Alva, Silver, Mill and Kirk burns, which drain the face of the Ochils, and these enable the position of the fault to be fixed with some accuracy. In Alva Glen, Lower Old Red volcanic rocks are brought against smashed and upturned red sandstones of Carboniferous age. In the Silver Glen, the red sandstones already mentioned are seen to overlie white sandstone, blaes and fakes with thin coals dipping steeply south off the fault. Between the volcanic rocks and the Carboniferous sediments there is a dolerite intrusion which presents chilled edges to the volcanic rocks, and is crushed on its south side against the Carboniferous. In the Mill Burn, blaes, fakes

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and sandstone are almost vertical against the fault. A dolerite intrusion is found between the volcanic rocks and the Carboniferous, but here it appears to have chilled margins on both sides. In the Kirk Burn again the dolerite shows a chilled margin against the volcanics while it is smashed and broken along its junction with the sediments. It seems probable, therefore, that there has been repeated movement along the line of the Ochil Fault. It is still a notable line for earthquake tremors.

Along the western side of the basin, at the margin of the 50-ft. terrace on the south side of the River Devon and east of Tullibody Bridge, coarse white friable sandstones occur, which are referable to the Millstone Grit Series. This view is confirmed by the fact that in Tullibody Mine, at the north end of Gunther's Wood, the Coalsnaughton Main Coal, lying near the base of the Coal Measures, was formerly wrought at the outcrop. Bores on Knowfaulds and on the ground east of Tullibody show that there also Millstone Grit strata are present at the surface.

Mr. Haldane has extended the revision of the Clackmannanshire coalfield to the Clackmannan and Kincardine-on-Forth districts. Part of the ground is occupied by much faulted strata of Coal Measures age, to the east of which the Millstone Grit forms the higher ground of Tulliallan Forest and Bath Moor. The only stream of importance in this area is the Black Devon and, apart from the numerous partial sections seen along its course, natural rock exposures are few. The Cherry and Splint Coals, with their associated strata, are seen in the Devon 400 yds. west of Mary Bridge to the north-west of Clackmannan, while the Coalsnaughton Main is exposed where the river flows along the north of Birkhill Wood, 2 miles north-east of the same town. The district contains very many old workings, of most of which no records can now be traced. Of the numerous disused sandstone quarries the one at Craigrie, a mile south-west of Clackmannan, is the most interesting, as it furnishes an excellent section of the Nine-Foot Coal. The details of this section are :—

	Ft.	in.
Grey fakes	6	–
Black blaes	–	6
COAL	–	8
Fakes	–	6
Coaly rib	–	1
Fakes with clayband nodules	–	8
Sandstone	–	4
Clayband ironstone	–	1
Sandy fireclay	–	3
Flaggy sandstone and fakes	4	6
Blaes with thin clayband ribs and nodules	1	11
,, ,, ,, ,, "mussels"	1	7
Black blaes with fish remains	–	3
NINE-FOOT COAL, with 4-in. of parrot on top	9	–
Fakes	1	–
Massive, yellowish-white sandstone - At least	25	–

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Glacial and Recent.

Outside the limits of the 100-ft. raised beach the ground is covered by a thick mantle of boulder clay containing many boulders derived from the Ochil Hills and from the Highlands to the north-west (*cf.* above, p. 49). Striae observed on the volcanic rocks of the Ochils indicate a south-easterly ice-flow, but the marked east-and-west orientation of the drumlins near Clackmannan shows that there the movement was in conformity with the general movement of the ice through the Central Valley.

Around Alloa the 100-ft. beach is well developed. Its margin has now been traced, generally as a well-marked feature, from Tullibody to Kincardine-on-Forth. Its deposits are mainly sands and clays, and at Hilton Brick Works near Alloa, dark chocolate clay, 30 ft. thick, is being worked for the manufacture of bricks, sanitary ware, &c. Clays of the 100-ft. beach were also formerly wrought to the north of Clackmannan.

The River Devon, below Tillicoultry, meanders through the flat 50-ft. carse lands, composed of a stiff brown clay. Upon the carse well-marked deltaic cones have been formed by streams issuing from the Ochil Hills, and on these the villages are built. Where the Black Devon traverses the deposits of the 50-ft. beach to the south-east of Alloa, small specimens of *Cardium* and of *Mytilus* have been obtained from a shell-bed in some of the blue clays. This beach has been more or less distinctly followed as far as Kincardine.

A deep buried channel runs up the Devon valley between Menstrie and Tillicoultry, as described in Mr. H. M. Cadell's 'Story of the Forth' (Glasgow, 1913, p. 90). A boring at Glenochil Distillery, Menstrie, passed through 337 feet of surface deposits, and did not reach rockhead. The height of the surface at this locality is only 35 or 40 feet above O.D.

LANARKSHIRE.

In the Douglas Coalfield, Mr. Macgregor and Mr. Manson examined and measured a number of sections in the Carboniferous Limestone Series at Bankend. The Poneil Water at this locality, along with its tributary the Hagshaw Burn, furnishes a fairly complete sequence from the Index Limestone to the Ell Coal and from the Macdonald Coal down to the well-known *Productus giganteus* limestone near the top of the Calciferous Sandstone sediments. A large suite of fossils has been collected from the various members of the Lower Limestone Group, but pending detailed examination of this material their correlation is held over.

As a supplement to the short account of the Douglas coalfield given in the 'Summary of Progress for 1919' (pp. 31–4,) the sections of the Limestone Coal Group exposed in the Hagshaw Burn may be shortly summarised. The Index Limestone, formerly exposed near the mouth of the burn, can no longer be examined

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in situ, but loose rocks that remain resemble the exposure in the old quarry at Longhill Burn some 2 miles to the east. The section of the Smithy and Dross Coals, and of the strata below and above them, is as follows :—

	Ft.	in.
Faky sandstone	3	–
Coal	–	7½
Fireclay	1	–
Blaes	1	6
Parroty blaes	2	–
Coal	–	6
Coaly fireclay	–	6
Faky sandstone with rooty top	9	6
Sandstone and faky sandstone	6	11½
Fakes and faky blaes	2	3
Firm blaes	3	3
Soft dark blaes	1	3
Firm blaes	3	3
Smithy Coal	2	3
Dark fireclay	1	4½
Coal	–	4
'Horn' or Wild Gas Coal	–	6
Dross Coal	3	10
Sandy fireclay	–	10
White rooty sandstone with irregular ribs of blaes	3	9
Blaes	1	–
Parroty blaes	1	3
Blaes	2	11
Faky sandstone	–	8
Blaes	3	5
Irony 'kingle' (*i.e.*, hard sandstone) lenticular up to	–	6
Blaes	1	6

The details of the section of the Ell Coal are :—

		Ft.	in.
Sandstone roof		–	–
Ell Coal	Head Coal	2	9
	Dark fireclay	1	6
	Coal	1	–
	'Horn' or Wild Gas Coal	–	11
	Coal	1	7

White rooty ganister-like sandstone floor.

No exposures of the Nine-Foot or Six-Foot Coals occur in the Hagshaw Burn, but it should be noted that there is a narrow troubled area to the south of the fault which cuts off the coals noted above at a point about 450 yds. from the junction with the Poneil Water. It is not yet certain in what part of the sequence these troubled beds lie. They are followed up-stream by a very

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fine exposure of the Macdonald Coal. The details of the section are :—

	Ft.	in.
Dark blaes with clayband nodules and ribs; *Lingula* predominant, some brachiopods	–	–
Clayband rib - - - - - 2½ in to	–	4
Dark shelly blaes, with brachiopods, &c. - -	1	6
Layer of flattened shelly nodules of irony limestone	–	2
Dark shelly blaes - - - - - - -	2	9½
Dark blaes, very shelly - - - - -	1	9
Limestone rib - - - - - -	–	7
Dark blaes, very shelly - - - - -	1	8
Macdonald Coal — Coal - - - - -	2	–
Macdonald Coal — Dark Fireclay - - -	–	4
Macdonald Coal — Coal - - - - -	2	10
Fireclay and balls - - - - - -	3	2
Dark parroty blaes with *Lingula* - - - -	1	–
Faky sandstone - - - - - 1½ ft. to	3	–
Blaes and hard fake ribs - - - - -	8	6
Fakes, faky sandstone and blaes - - at least	13	6½

There is a break in the sequence here but the Top Macdonald Limestone is not far below the base of the section just quoted. The marine beds overlying the Macdonald Coal, and the Lingula band which occurs a few feet below it, are very useful horizons in identifying the seam in the workings. Another exposure of the Macdonald Coal is seen in the Poneil Water nearly five-sixths of a mile east of the ford at Brockley; here it shows :—

	Ft.	in.
Shelly blaes (several feet thick) - - - -	–	–
Coal - - - - - - - - - -	1	6
Fireclay - - - - - - - - -	1	0
Coal - - - - - - - - - -	–	7
Fireclay - - - - - - - - -	–	8
Coal - - - - - - - - - -	–	7½
Fireclay - - - - - - - - -	3	6

The attenuation of the seam in an easterly direction is also a characteristic of all the higher coals; on the eastern margin of the Douglas-Ponfeigh coalfield, however, they appear in still thicker development.[1]

The Macdonald Limestones are exposed at several localities and from the blaes associated with the highest of these *Posidonomya corrugata* has been obtained. The Hawthorn or Main Limestone is also seen at various places in the Poneil Water and Hagshaw Burn, and shows 6 or 7 fathoms of very fossiliferous nodular limestones and limy fakes, containing *Lithostrotion* bands, large *Producti* and corals. A 6-in. or 7-in. coal underlies it, while above it are 4½ ft. of faky sandstone and 2 ft. of a very white ganister-like sandstone with a nodular top. This sandstone

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 33.

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forms an exceedingly useful index in working out the details of the various partial sections. On top of it occurs a lenticular sandy ironstone, apparently worked in former days. This band reaches a thickness of 8 in. but is often absent; above it comes a slaty pyritous rib about ½ in. thick containing fish remains, and forming the base of a thick series of dark crumbling fossiliferous blaes.

5. Borings for Oil at D'Arcy and West Calder.

Periodical visits to the experimental borings for oil have been continued and the samples of sediments and pieces of rock have been examined by Mr. Tait.

D'Arcy Oil Well (1-in. Sheet 32 Scotland, 6-in. Sheet, Edinburgh, VIII., S.E.).—This boring, situated about 1 mile S.S.W. of the mining village of Chesterhill (3 miles S.E. of Dalkeith) commences in the Lower Limestone Group where it rises in a clearly defined anticline that forms a local fold along the general anticlinal uplift between the Roman Camp and Cousland on the eastern side of the Midlothian Coal Basin. South of the boring the anticline is crossed by a fault and several others have been proved in colliery workings both to the east and west of the local anticline.

The boring commences a few feet below the outcrop of the D'Arcy Limestone (No. 2 or Skateraw Limestone), the outcrop workings forming a semicircle round the site of the boring. At a depth of 27 fathoms it passes through limestone beds containing marine shells interbedded with sandstones and then continues in an alternating series of shales, sandstones, fireclays and marls to a depth of 117 fathoms. At 118 fathoms there occurs an oil-shale, approximately 15 ft. thick, and resting on a sandstone that gives off a large quantity of gas. The commercial value of the oil-shale cannot be estimated from the samples obtained by the method of drilling, but there is little doubt that it is one of the bands towards the top of the Oil Shale Group.

From 118 fms. to 150 fms.—the present depth of the boring—the strata are mainly sandstones, with a band of white limestone, 10 ft. thick at 126 fms. Traces of a coal occur at 139 fms. At 150 fms. a fine-grained white sandstone yields brackish water with traces of oil.

West Calder Oil Well.—In the 'Summary of Progress for 1919' an account of this boring was given to a depth of 543 fms. The present depth is 651 fms., the strata between 543 fms. and 650 fms., consisting of black shales with interbedded bands of volcanic ash. The boring is now in sandstone yielding salt water in considerable quantity. The absence of sandstones between 215 and 650 fms. is remarkable and it would appear that sandstones of the Granton Sandstone Group have not yet been reached.

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III.—PETROGRAPHICAL WORK.

1. England and Wales.

As far as England and Wales are concerned most of the petrographical work has been in connection with special enquiries from private individuals and Government departments. An investigation into the size and nature of dust-particles aspirated from the air of mines and factories has been carried out at the request of the Home Office, and the results will be in due course embodied in the reports of that department. Dr. Thomas at the invitation of the Society of Antiquaries has investigated the probable source of the 34 foreign stones that constitute all that remains of the inner circle and inner horse-shoe of Stonehenge. These stones have come within the purview of many geologists, who have suggested in general terms possible sources in North and South Wales, Devon, Cornwall, and even Scotland. They were simple standing-stones, not capped by lintels, and show no signs, except in the case of one prostrate stone, of ever having been morticed, as are the sarsens of the outer circle and the trilithons. That they were dressed on the spot and considerably reduced in size has been abundantly proved by the copious fragments found in the soil during the recent excavations by H.M. Office of Works.

The most interesting feature of these stones is that of the 34 now remaining, 29 are all of the same type (blue stones) and are formed of a bluish green even textured diabase that is characterised by an abundance of irregular felspar crystals (albite oligoclase) that appear in the hand-specimen as pinkish or white spots ranging from the size of a pea to that of a hazel nut.

This spotted character, not commented upon by earlier observers, at once removes the rock in question from the generality of diabases, and renders the identification of the source a matter of greater certainty.

A spotted diabase of identical appearance, mineralogical composition and microscopic character is the dominant rock of the Prescelly Mountains in Pembrokeshire. These hills rise more or less abruptly from the plain of Western Wales and owe their form and preservation largely to the sills of diabase which extend through them from Rosebush on the west to Crymmych on the east.

Such spotted diabases are, as far as Great Britain is concerned, practically restricted to the Pembrokeshire area and therefore the Prescelly Mountains must be regarded as the most probable ultimate source of the Stonehenge ' blue stones.'

It is interesting to note that in association with the spotted diabase of Prescelly there occurs a considerable mass of banded and minutely spherulitic rhyolites. These rocks, grey in colour and weathering with a white crust in which the banding shows most clearly, are identical with three stones of finely-banded

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rhyolite represented amongst the foreign stones of Stonehenge. It, therefore, appears that 32 out of the 34 foreign stones may, with little doubt, be referred to Pembrokeshire sources. The remaining examples of slaty sedimentary rocks and the micaceous sandstone of the so-called 'altar stone' are not in disagreement with a Welsh derivation.

As far as Salisbury Plain is concerned the foreign origin of these stones is unquestionable, and various theories have been propounded to explain their presence in a region so remote from all possible sources. The theory most generally accepted and first put forward by the late Prof. Judd, was to the effect that they had been transported by ice to the Plain from some region to the north; and he explained the absence of all smaller stones of the same character by assuming that these had been utilised for mill-stones, gate-posts, &c. As pointed out by Mr. Stevens and other workers, there is no evidence of the existence of any masses of rock of these types, either large or small, in Wiltshire, except within the area of Stonehenge itself. Further, the ice that was supposed to carry these boulders to Salisbury Plain would have had to select carefully from all the rocks over which it passed, not only as regards rock-type, but also as regards the size of the transported material. The idea that such rocks had been glacially carried to the Plain must be dismissed as being contrary to the mass of geological evidence. With the object of eliminating all other possible sources, especially those of a proximate nature, a careful revision was made of the rock-types represented amongst the large boulders stranded on the coastal regions of Hampshire between Selsey and Bournemouth. All specimens available including those noted by Godwin Austin, Clement Reid, Osborne White, and others, have been examined, with the result that in no case has a Stonehenge type been detected. We may assume, therefore, that these boulders, often of considerable size and occurring relatively near to Salisbury Plain were either unknown to, or disregarded by, the builders of Stonehenge. In view of the last-mentioned fact and the still more important uniformity of type presented by the Stonehenge 'blue stones' and rhyolites, the inevitable conclusion is that the stones were brought direct from their parent source by human agency.

In Pembrokeshire, boulders of these rocks, dislodged by the ice that passed over the Prescelly Mountains, lie scattered over the stopes and low ground to the south and south-east, and masses of suitable size could be easily collected. That the monoliths were derived from a glaciated region, a feature that at once rules out Devon and Cornwall as possible sources, is indicated by the recent find at Stonehenge of a large flake from one of the 'bluestones,' which shows good glacial striations.

2. Scotland.

Petrographical work in connection with the forthcoming memoir on the Island of Mull has been carried out by Dr. Thomas

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and Mr. E. B. Bailey. Special attention has been paid to the classification of the basalt lavas of Sheet 44. It has been found that they are roughly divisible into two petrographical groups olivine-rich and olivine-poor respectively. Of these, varieties rich in olivine preponderate in the lower part of the volcanic pile, and the olivine-poor varieties in the upper part.

In the Ben More region the group rich in olivine is roughly 3,000 ft. in thickness, and it is clear in the field that the group poor in olivine which succeeds is of approximately the same magnitude.

In previous reports the basalts poor in olivine have been spoken of as andesites, and this appellation has not infrequently been applied to certain olivine-rich varieties that have a pale tint in the hand-specimen. The prevalence of pale lavas associated with, but distant from, the mugearite lava-zone of Ben More was, perhaps, first recognised by Sir Archibald Geikie. The pale colour is now shown to be correlated with a poor development of magnetite which results from the decomposition of olivine. In the Ben More region it would seem that the olivine of the lavas in the lower part of the olivine-rich group of basalts was more ferruginous than that of lavas on higher horizons, for it yielded on decomposition abundant secondary magnetite. It is one of the most interesting features of Mull geology that within a circle 14 miles in diameter, none of the basalt lavas have retained their olivine in a fresh condition. This circle centres on the hill-country between Glen Cannel and Glen More, and includes Ben More well within its circumference. The definite character of this phenomenon will be recognised when it is said that out of 336 olivine basalts sliced from within the circle none has retained any fresh olivine, while of 44 specimens of similar rocks sliced from outside the area in question, 34 carry this susceptible mineral in a more or less unaltered condition.

Side by side with this replacement of olivine by chlorite and serpentine, there is a widespread development of albite and epidote filling cracks and vesicles. These phenomena are attributed to pneumatolitic action connected with the Mull centre of activity. A full discussion must be deferred until the publication of the Memoir, but it is proper to say that many of the features have already been dealt with in the writings of the late Prof. Judd.

IV.—CHEMICAL WORK.

During the year work in connection with the Special Report on British Refractory Materials has been continued, and 18 fireclay analyses completed for inclusion therein.

In addition, analyses were made of one rock from Leicestershire for Memoir Sheet 169 and of eight from Aberdeen and Banffshire for Memoir on Sheets 86 and 96, the details of seven being included in this Report.

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As examples of the composition of British fireclays analyses of six are given below :—

Old Mine fireclay, black, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4354; Lab. No. 610.

Old Mine fireclay, white, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4355; Lab. No. 611.

Fireclay, No. 1 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4357; Lab. No. 613.

Fireclay, No. 4 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4356; Lab. No. 612.

'*Nonsuch Fire-earth*'—brown-green variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5703; Lab. No. 653.

'*Nonsuch Fire-earth*'—'white' variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5709; Lab. No. 659.

Lab. No.	610	611	613	612
SiO_2	45·22	77·71	58·18	62·67
TiO_2	1·08	1·38	1·27	1·15
Al_2O_3	31.32	13·46	26·36	22·30
Fe_2O_3	1·76	1·04	1·61	2·90
MnO	·03	·02	·03	·03
CaO	·34	·05	·29	·23
MgO	·51	·23	·69	·66
K_2O	·94	·06	1·67	·48
Na_2O	·23	·35	·20	·38
Li_2O	trace	trace	trace	trace
H_2O at 105° C.	3·00	·91	1·56	1·61
H_2O above 105° C.	11·30	4·81	8·19	7·86
P_2O_5	·07	·05	·12	·07
FeS_2	·01	·05	·04	·02
Organic matter	4·18	·12	·21	·12
CO_2	·04	·03	·01	·04
Total	100·03	100·27	100·43	100·52
Loss on ignition	18·52	5·94	10·17	9·58

Lab. No.	653	659
SiO_2	85·65	91·30
TiO_2	·36	·35
Al_2O_3	5·44	3·77
Fe_2O_3	4·21	1·98
FeO	·23	·11
MnO	·03	·02
CaO	·40	·34

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Lab. No.	653	659
MgO	·65	·44
K_2O	1·19	·60
Na_2O	·10	·01
Li_2O	nt. fd.	nt. fd.
H_2O	1·98	1·32
P_2O_5	·05	·03
FeS_2	nt. fd.	nt. fd.
CO_2	nt. fd.	nt. fd.
Total	100·29	100·27

Results calculated on samples dried at 105° C.

The following are analyses of rocks of the Older Igneous Series of Portsoy and district :—

Pyroxenite.—Line of crags, inside west edge of Whitehill Plantation, 300 yds. W. by N. of Whitehill Farm; ¾ mile W. of Rothiemay Station. One-in. map, 86; 6-in. Aberdeen, 17, S.W. Slice No. S. 20363; Lab. No. 640.

Labradorite Rock.—Knob, just above high-water mark, 200 yds. W.S.W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 2213; Lab. No. 639.

Epidiorite.—Sea-cliff, 70 yds. W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 20364; Lab. No. 641.

Lab. No.	640	639	641
SiO_2	49·76	48·85	48·65
TiO_2	·11	·29	1·30
Al_2O_3	2·70	26·51	14·92
Fe_2O_3	2·56	1·28	1·31
Cr_2O_3	·34	nt. fd.	nt. fd.
V_2O_3	·07	nt. fd.	nt. fd.
FeO	4·26	·95	8·03
MnO	·17	·13	·11
(CoNi) O	nt. fd.	·03	nt. fd.
BaO	nt. fd.	·01	trace
CaO	15·56	12·19	8·79
MgO	22·03	1·64	8·92
K_2O	·18	·96	1·76
Na_2O	·10	3·64	2·56
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·24	·25	·23
H_2O above 105° C.	1·85	1·57	1·26
P_2O_5	·05	·08	·17
FeS_2	nt. fd.	nt. fd.	nt. fd.
Fe_7S_8	nt. fd.	nt. fd.	1·07
CO_2	·05	1·96	·96
Total	100·03	100·34	100·04

Anal.—E. G. Radley.

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Below are four analyses of the Younger Igneous Series forming part of the Huntly Igneous Mass :—

Peridotite.—Quarry on east side of road, midway between Boghaugh and Broadlands, ⅓ mile N.E. of Broadlands, 3 miles W.N.W. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20360; Lab. No. 634.

Olivine Gabbro.—Right bank of River Deveron, 200 yds. N. of Cairnford Bridge, 2¾ miles W. by N. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 19680; Lab. No. 635.

Troctolite.—Craighead Quarry, in wood N. of road, ⅓ mile E. of Cairnford Bridge, 2 miles W. of Huntly. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20361; Lab. No. 636.

Norite.—Ladysmith Quarry, W. of Keillenknowes, 4 miles N.N.E. of Huntly. One-in. map, 86; 6-in. Aberdeen, 17, S.E. Slice No. S. 20362; Lab. No. 637.

Lab. No.	634	635	636	637
SiO_2	35·72	48·11	44·29	48·58
TiO_2	·36	·75	·09	3·44
Al_2O_3	10·99	17·86	25·26	13·82
Fe_2O_3	3·73	·43	·04	1·14
Cr_2O_3	·37	·13	·09	nt. fd.
V_2O_3	·09	·05	·03	nt. fd.
FeO	6·37	5·20	3·28	12·73
MnO	·06	·30	·25	·32
(CoNi) O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	trace	nt. fd.	trace	nt. fd.
CaO	3·28	12·42	11·32	9·43
MgO	26·62	9·53	7·94	5·21
K_2O	·43	·64	·49	·76
Na_2O	·58	2·34	2·30	2·87
Li_2O	nt. fd.	nt. fd.	trace	nt. fd.
H_2O at 105° C.	·58	·14	·33	·05
H_2O above 105° C.	8·72	·84	2·57	·36
P_2O_5	·14	·07	·07	·64
FeS_2	·12	·11	·12	·08
Fe_7S_8	1·49	·68	·95	·38
CO_2	·38	·54	·83	·37
Total	100·03	100·14	100·25	100·18

Anal.—E. G. Radley.

Quartz-Diorite Porphyrite.—Elongated boss, unconformably overlain by Keuper Marl and drift. N.W. corner of Sapcote Quarry. One-inch map 169. Six-inch Leicester, 43 N.E. Slice No. E. 12011. Lab. No. 633.

SiO_2	61·84
TiO_2	·66

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Al_2O_3	15·51
Fe_2O_3	1·90
FeO	2·84
MnO	·08
(CoNi)O	nt. fd.
BaO	·02
CaO	5·03
MgO	3·22
K_2O	1·98
Na_2O	4·12
Li_2O	nt. fd.
H_2O at 105°C	·34
H_2O above 105°C	1·97
P_2O_5	·21
FeS_2	·10
CO_2	·52
Total	100·34

Anal.—E. G. Radley.

V.—PALÆONTOLOGICAL WORK.

1. England and Wales.

The collections of fossils have been enriched by some valuable donations. Miss C. A. Raisin presented a large collection of Jurassic Mollusca, formerly in the possession of the late W. H. Hudleston. The specimens are well localized and are of fine quality, while many of them are of special interest, since they serve to illustrate some of Hudleston's published work. Mr. G. W. Lamplugh presented his fine collection of sponges from the Upper Chalk of Yorkshire. This comprises many specimens suitable for museum exhibition, and a wealth of material for special study. A collection of 500 specimens of Mollusca from the Crag of Oakley was received from Mr. F. W. Harmer.

Dr. Kitchin and Mr. Pringle examined several sections in the Gault of different localities. At Copt Point, Folkestone, they searched for the horizon characterised by the *catillus*-fauna, which occurs in the Rostratus Beds of sandy facies in Wiltshire and the Isle of Wight. It was found to occupy a position at Folkestone near the base of Price's Bed XI., about 15 ft. above the top of Bed IX. In a temporary opening made in an old clay-pit at Long Crendon, in Buckinghamshire, the clay was found to be Upper Gault, showing an ochreous basement-bed almost identical in character with that seen in the case of the overlapping Upper Gault near Leighton Buzzard, which there rests upon the uppermost parts of the Lower Greensand. At Long Crendon, the basement-bed occupies a position less than 3 ft. above a Purbeck limestone.

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Visits were also made to Cambridge, to examine a section in the Cambridge Greensand and Gault, and to the Leighton Buzzard neighbourhood, to continue observations on the Gault and contiguous deposits, begun unofficially by Dr. Kitchin and Mr. Pringle. At the Norman Cement Co.'s large pit at Cambridge, some excavations had laid bare the Cambridge Greensand, which is rarely so well seen. The phosphate-bed was observed to rest upon an uneven and bored floor of unfossiliferous Gault. It was not possible to determine the exact horizon of this uppermost Gault, but it is highly probable from its lithological characters and the absence of fossils in it, that it corresponds with a level well above the base of Bed XI. of Folkestone. This is in agreement with the observations made by Prof. Fearnsides many years ago in the Barnwell pit. The amount of erosion to which the Gault was subjected at these localities was, therefore, less than in some other pits at one time opened along the outcrop, where the phosphate-bed contained some of the fossils of Bed IX. of Folkestone, in *remanié* condition.

Further collecting of fossils from the nodules of the Tardefurcata Bed, below the Interruptus Zone south of Leighton Buzzard, has added considerably to our knowledge of the fauna of that horizon, which is there well characterised by species of *Leymeriella*. The results of collecting from the phosphate-nodules in the sands immediately below the Gault at West Dereham, Norfolk, favour the view that at that locality the Tardefurcata Zone is present below the Interruptus Clay, as in Bedfordshire.

Mr. Pringle visited the sites of numerous borings during the year. The results of the borings at Bourne End, Marlow and Slough have been incorporated in the Memoir on the Water Supply of Buckinghamshire and Hertfordshire. Upwards of a dozen borings in Norfolk have given interesting geological information, which has not yet been made available for publication. Light has been thrown on the underground extension of the Jurassic formations in that county. A boring at North Ferriby, near Hull, has shown that the Red Chalk there rests upon a clay which belongs either to the basal part of the Kimmeridge Clay, or to the upper part of the Corallian Series. The results of Mr. Pringle's examination of the cores at a deep boring at Yate, Gloucestershire, are published herewith as an Appendix (p. 92).

A piece of core from the Keele Beds in a boring at Slang Lane, Wellington, submitted to Mr. Pringle for examination, yielded a new insect-wing. This has been described by Mr. H. Bolton as *Archimylacris pringlei* in a paper read before the Geological Society.

Good progress has been made in museum revision-work. Mr. Buckman has continued the re-naming of the Jurassic ammonites. Mr. Chatwin has carried out curatorial work on

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the collection of Tertiary Mollusca, and has devoted much time to the important task of registration.

The following specimens in the Museum have been figured and described :—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1918.

(PUBLISHED 1920.)

A Monograph of the British Ordovician and Silurian Bellerophontacea. (Part 1.)

By DR. F. R. COWPER REED, M.A.

Sinuites anceps *Reed*, pl. i, figs. 1, 1a, 2, 2a, p. 5.
„ bilobatus (*J. de C. Sow.*), pl. i, figs. 8, 8a, b, p. 7.
„ elongatus (*Portl.*), pl. i, figs. 12, 12a, 13, 13a, p. 9.
„ semirugosus *Reed*, pl. ii, figs. 13, 14, 16, p. 13.
„ soudleyensis *Reed*, pl. ii, figs. 18, 18a, b; pl. iii, fig. 3, p. 13.
Oxydiscus acutus (*J. de C. Sow.*), pl. iv, figs. 1, 1a, b, 2, 2a, p. 19.
„ ? llanvirnensis (*Hicks*), pl. iv, figs. 10, 10a, 11, 11a, p. 22.
Cyrtolites nodosus (*Salt.*), pl. v, figs. 1, 1a-c, 2, 2a, b, p. 25.
„ „ *var.* llandoveriana *Reed*, pl. v, figs. 3, 3a, 4, p. 26.
Kokenospira lingualis (*Salt.*), pl. vi, fig. 16; pl. vii, figs. 1, 1a, b, p. 35.
Tetranota hippopus (*Salt.*), pl. viii, fig. 16, p. 43.

The Pliocene Mollusca of Great Britain. Volume ii., Part 1.

By MR. F. W. HARMER, M.A.

Scala (Spiniscala) trevelyana (*Leach*), pl. xlviii, fig. 14, (2 views), p. 528.
„ (Lamelliscala) frondosa (*J. Sow.*), pl. xlviii, fig. 22, (2 views), p. 532.
Pyrgulina scalaris (*Philippi*), pl. xlix, fig. 43, (2 views), p. 577.
„ spiralis (*Montagu*), pl. xlix, fig. 44, (2 views), p. 578.
Alvania (Massotia) lactea (*Michaud*), pl. l, fig. 41, (2 views), p. 621.
„ (Galeodina) carinata (*Da Costa*), pl. l, fig. 44, (2 views), p. 620.
Manzonia costata (*Adams*), pl. l, fig. 48, (2 views), p. 624.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY VOLUME LXXVI.

BY DR. F. J. NORTH.

Tylothyris laminosa (*M'Coy*), pl. xiii, fig. 16, p. 197.
Spirifer plicatosulcatus *North*, pl. xiii, figs. 17a, b, p. 193.

IN THE GEOLOGICAL MAGAZINE, VOLUME LVII., 1920.

By DR. F. R. COWPER REED, M.A.

Homalonotus (Burmeisterella) elongatus (*Salt.*), p. 343.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME V.

By DR. C. W. ANDREWS, F.R.S.

Patanemys bartonensis *Andrews*, text-fig. 2, p. 149.

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IN TYPE AMMONITES, VOLUME iii.

By MR. S. S. BUCKMAN.

Retenticeras retentum (*Simpson*), pl. clxvi, figs. 1, 2.
Pavloviceras bathyomphalum *S. Buckm.*, p. 18.
„ omphaloides (*J. Sow.*), p. 18, (2 specimens).

IN THE REPORT OF THE YORKSHIRE PHILOSOPHICAL SOCIETY, 1919.

British Fishes and Reptiles—Pliocene to Holocene.

By MR. ALFRED BELL.

Notidanus griseus ? *Cuv.*, pl. i, fig. 4, p. 9.
Acipenser toliapicus *Ag.*, p. 12.

IN THE ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DU NORD, LILLE, TOME XLIII.

By DR. P. PRUVOST.

Leaia salteriana *R. Jones*, pl. ii, figs. 1-3; text-fig. 2, p. 262.

2. SCOTLAND.

Fossils were collected from Carboniferous Rocks in the Central coalfield, and from Mesozoic areas in the island of Mull and Sutherlandshire.

The Carboniferous fossils were obtained partly from natural exposures and partly from borings. In several instances the determination in borings of important horizons, about which there was doubt, was successfully achieved from palæontological evidence.

A preliminary examination of fossils collected by Mr. Manson on the west coast of Mull has led to the recognition of Rhaetic, Hettangian, and Sinemurian strata referred to on p. 35.

Detailed collecting, on zonal lines, was made in the Jurassic rocks of the Brora district in Sutherland, but as the work was undertaken late in the year, the critical examination of the fossils could not be begun in time to be summarised here.

VI.—PHOTOGRAPHIC WORK.

In England and Wales 26 views of geological subjects have been added to the collections.

In Scotland 170 negatives of landscapes of special geological interest in the counties of Argyll, (Morvern and Mull), Forfar and Kincardine were obtained.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

In illustration of Vol. VII. of the 'Special Reports,' a temporary exhibit has been prepared of the lignites, jets, Kimmeridge oil-shale, mineral oils and cannel coals of Great

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Britain. This exhibit, which includes a sample of the oil from the Hardstoft boring in Derbyshire, has been the object of much public interest.

Dr. J. Morrow Campbell lent a large suite of specimens in illustration of his paper on the Tungsten Deposits of Burma, and Mr. W. S. Lockhart has lent a Chinese screen, which is a very beautiful example of skilful artistic treatment of a colour-banded slate.

Although much work is still necessary before the Museum recovers from the disorganisation caused by the war, it has been possible this year to make all parts accessible, and the work of arrangement is now in progress.

List of Donations during the year 1920.

Acton, A., Esq.—Two nodules from sandy limestone shales, also sections and specimens of silica.

Anderson, Dr. Victor C.—Specimen of oil shale from Grand Valley, Colorado, with photographs.

Andrews, Charles T., Esq.—Specimens of phenakite crystals, also enhydros, from Brazil.

Barrow, Mrs. R.—A fine specimen of *Ammonite* from the Mammillatus Bed of West Dereham, Norfolk.

Bolckow, Vaughan & Co., Messrs.—A specimen of fused silica-brick, also akermanite crystals.

Brown, G. F., Esq.—A specimen of *Lima hoperi* Mant., from the Upper Chalk of Purley.

Buck, the Hon. E. C., M.Inst.C.E., F.G.S.—specimens of petroleum (pitch) from the Waini and Pomeroon districts, British Guiana.

Carley, G., Esq.—A fine group of pyrites crystals from the Gaurano Mine, Tuscany.

Carruthers, R. G., Esq., F.R.S.E.—Two specimens and a series of thin sections of *Cryptophyllum hibernicum* R. Carr., from the Carboniferous Limestone of Bundoran, Donegal Bay, Ireland.

Dewey, H., Esq., F.G.S.—Specimens of marcasite and pseudomorphs, also ancient slags.

Edge, Lieut. A. B.—A specimen of siliceous sinter, from Devonshire.

Garnett, C. S., Esq.—Two small specimens of red fluorspar from Ashover.

Gomme, A. T., Esq.—Part of a dermal spine of *Polacanthus*, from the Wealden of Cuckfield, Sussex.

Greenly, Dr. E.—A specimen of Asteroid from the Middle Calcareous Grit of Filey Brig, Yorkshire.

Hackney, Noel G., Esq., M.Inst.M.M.—A drawing of the Southampton Common Well, by Henry Penrose, Engineer, 1842, showing strata to 560 feet. Scale, 1 inch—4 feet.

Hall, T. Clifford, Esq., Assoc.M.Inst.M.M., F.G.S.—Minerals and rock specimens from Abyssinia; also specimen of tin vein from Roche, Cornwall.

Harmer, F. W., Esq., M.A., F.G.S.—A large series of Crag Mollusca from Oakley, Suffolk.

Holloway & Co., Ltd., Messrs. G. T.—Cobaltite from the Cloncurry district, Queensland, Australia.

Hooker, Lady.—Copper ore and graphite from Sikkim.

Kidner, N. W., Esq.—A fragment of upper jaw of the crocodilean genus *Steneosaurus*, from the Cornbrash near Thrapston.

King, W. B. R., Esq., M.A., F.G.S.—Seven specimens of *Griffithides shunnerensis* King, from the Millstone Grit of Shunner Fell Well, near Hawes, Yorkshire. Also 6 specimens of volcanic rocks from the Rhine valley.

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KITCHIN, F. L., ESQ., M.A., PH.D., AND PRINGLE, J., ESQ., F.G.S.—A series of fossils and rock-specimens from the Lower Greensand, Gault and Cenomanian of the Leighton Buzzard district.

LAMPLUGH, G. W., ESQ., F.R.S.—A large suite of fossils (mostly sponges) from the Upper Chalk of Yorkshire and a few fossils from the Red Chalk of Yorkshire.

LAVER, H. E., ESQ.—Two boxes of Chinese paints.

LEIGH, THE RIGHT. HON. LORD.—Specimens of pyrrhotite from Griqualand.

LIBERIAN DEVELOPMENT CO., THE.—Specimens of phenakite sand from Liberia.

MARSHALL, FRANCIS, ESQ.—Pyrites on quartz.

MAYO, H. J. A., ESQ.—A fossil cone from the Ferruginous Sands of Shanklin, Isle of Wight.

MERRICKS, FRANK, ESQ., C.B.E., A.R.S.M.—A gold nugget with crystal faces, mounted as a pin.

MESOPOTAMIA, THE CIVIL COMMISSIONER IN.—A set of economic rock specimens from Mesopotamia and Southern Kurdistan. (Collected by A. H. Noble, Esq.).

NEWBOLD, MRS. ELEANOR T.—Model of a silver mine at Guanajuato, Mexico.

OSMAN, C. W., ESQ.—Crystals of inyoite from New Brunswick. Granite specimens from boring at 'Ontie Down,' Chagford. Model of twin crystal of pyrites.

OWENS, DR. J. S., F.G.S.—A fine example of artificial percussion cones in flint.

PAIN, MESSRS. A. C. D., AND R. S.—Three quartz pseudomorphs after octahedral scheelite crystals, from South Zeal, Sticklepath, Okehampton, Devonshire.

PENTLAND, THE RIGHT HON. LORD.—A walking stick of black limestone, silver mounted, with inscription 'Presented to H.E. Lord Pentland by D. Kristna Rao.'

PERKIN, DR. F. MOLLWO, C.B.E., PH.D., F.I.C.—Specimens of calcite from Nottingham.

PICKERING, CAPT.—Specimens of 'boxstone' from Wiltshire.

PRINGLE, J., ESQ., *see* KITCHIN, DR. F. L.

RAISIN, MISS C. A., D.SC., F.L.S., F.G.S.—A fine collection of about 4,000 fossils, chiefly Jurassic mollusca, formerly in the possession of the late W. H. Hudleston, F.R.S.

REINHOLD, DR. TH.—Two specimens of limestone used for lime at Maastrict and Kinrade, Holland.

RENWICK, R., ESQ.—Specimen of Stammarhan roofing stone; paving stone with ripple marks; paving stone with circular casts.

RODDA, MRS. (per W. WHITAKER, ESQ.)—Felspar twin.

SANDERS, A. B., ESQ.—Specimen of manganese ore from Brazil.

SCHAVERIEN, —., ESQ.—Three specimens of black spinel: (*a*) raw material, (*b*) cut but unpolished, (*c*) polished.

SMITH, BERNARD, ESQ., M.A.—Specimens of blende and calcite from Shropshire.

SOAMES, E. R., ESQ.—Specimens of *Stigmaria ficoides* from the Ganister of Wolsingham.

SOUTH DURHAM, STEEL AND IRON CO., LTD.—Specimens of slag, etc.

STAMP, L. DUDLEY, ESQ., M.SC.—Three specimens of associated lead and zinc ores from Lontzen Mine, Belgian Prussia.

STRAHAN, SIR AUBREY, K.B.E., F.R.S., etc.—Calamine from Holywell, and hæmatite from the Coal Measures near Frizington.

TEMPEST, P. C., ESQ., C.B.E., M.INST.C.E.—A series of photographs of the landslip in Folkestone Warren, with descriptive map.

WARREN, A., ESQ.—Specimen of picrite from Knowle Hill, Newton Abbot, Devon.

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WARREN, S. HAZZLEDINE, ESQ., F.G.S.—A series of specimens, mostly fossils, from certain wells in or near London. A large rough-worked block from the implement-bearing scree, Graig Lwyd, near Penmaenmawr; also a more finished but imperfect implement. Also two Roman blocks of calcareous tufa from East Wear Bay.

WHITAKER, W., ESQ., B.A., F.R.S.—A necklace of clear facetted amber beads.

WAY, REV. DR. J. P.—A specimen of pseudomorphous quartz from South Zeal Mine, Cornwall.

WHITE, FRANKLIN, ESQ., M.INST.M.M.—Mineral specimens from Broken Hill, Rhodesia.

WILSON, M. E., ESQ.—A series of samples representing the products of the Canadian China Clay Company, Amhurst Township, Ottawa, Canada.

WRIGHT, C. S., ESQ.—A twinned crystal of albite.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

SIX-INCH REFERENCE MAPS.

The following 24 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference :—

Hertfordshire, 19 S.E.; 20 S.W., S.E.; 27 N.E., S.E.; 28 N.W., N.E., S.W., S.E.; 34 N.E., S.E.; 35 N.W., N.E., S.W., S.E.; 39 N.E., S.E.; 40 N.W., S.W.
Kent, 8 S.W.
London, 8 S.W., S.E.
Middlesex, 1 N.E., S.E.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Special Reports on the Mineral Resources of Great Britain :—

Vol. VI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces — Dolomite. Resources and Geology. 2nd Edition. 241 pp.; 3 plates; 8 text-figures. 1920. Price 7*s.* 6*d.* net.

Vol. VII.—Mineral Oil, Kimmeridge Oil-Shale, Lignites, Jets, Cannel Coals, Natural Gas. England and Wales. 2nd Edition. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., with contributions by W. Gibson, D.Sc., H. Dewey, B. Smith, M.A., C. E. N. Bromehead, B.A., J. Pringle. 125 pp.; 1 plate; 7 text-figures. 1920. Price 5*s.* net.

Vol. XII.—Iron Ores (*contd.*): Bedded Ores of the Lias, Oolites and Later Formations in England. By G. W. Lamplugh, F.R.S., C. B. Wedd, B.A., and J. Pringle. 240 pp.; 8 plates; 12 text-figures. 1920. Price 12*s.* 6*d.* net.

Vol. XIII.—Iron Ores (*contd.*): Pre-Carboniferous and Carboniferous Bedded Ores of England and Wales. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., W. Gibson, D.Sc., T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey. 123 pp.; 3 plates, 10 text-figures. 1920. Price 7*s.* 6*d.* net.

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Vol. XIV.—Refractory Materials: Fireclays. Resources and Geology. 243 pp.; 4 plates, 13 text-figures. 1920. Price 8*s.* net.

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Vol. XVI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite. Petrography and Chemistry. By Herbert H. Thomas, M.A., Sc.D., A. F. Hallimond, M.A., and Ernest G. Radley. 115 pp; 7 plates, 6 text-figures. 1920. Price 5*s.* net.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1919. 70 pp.; 3 text-figures. 1920. Price 2*s.* 6*d.* net.

The Geology of Anglesey. By Edward Greenly. 980 pp., 60 plates; 17 folding-plates, 246 text-figures. 1919. In two volumes. Price 3*l.* 3*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of 6-inch maps have been completed and deposited in the office for reference:—

Aberdeen, 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 43 N.W., N.E.; 44 N.W., N.E. } Solid and Drift of each.

Renfrew, 15 N.E. } Solid and Drift of each.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following 6-inch clean copies (Old Series Maps) and these are now completed and deposited in the office for reference:—

Kirkcudbright, 30 N.W., N.E., S.W., S.E.; 35 N.E., S.E.; 36 N.W., N.E., S.W., S.E.; 37 N.W., N.E., S.W., S.E.; 42 N.W., N.E., S.E.; 43 N.W., N.E., S.W., S.E.; 48 N.E.

Wigtown, 1 S.W., S.E.; 2 S.W., S.E.; 3 S.W.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1919. *See* above.

Special Reports on the Mineral Resources of Great Britain:—

Vol. XI.—Iron Ores (*cont.*): The Iron Ores of Scotland. By M. Macgregor, B.Sc., G. W. Lee, D.Sc., G. V. Wilson, B.Sc., with contributions by T. Robertson, B.Sc., and J. S. Flett, F.R.S. 240 pp; 18 text-figures. 1920. Price 10*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area IV. Paisley, Barrhead, Renfrew, and the Western Suburbs of Glasgow North and South of the Clyde. By L. W. Hinxman, B.A., F.R.S.E., E. M. Anderson, M.A., B.Sc., and R. G. Carruthers, F.G.S. 110 pp.; 8 plates, 5 text-figures. 1920. Price 6*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area VII. Including the Districts of Rutherglen, Hamilton and Wishaw. By the late C. T. Clough, M.A., LL.D., the late J. S. G. Wilson, E. M. Anderson, M.A., B.Sc., and M. Macgregor, M.A., B.Sc., with contributions by R. G. Carruthers and C. H. Dinham, B.A. 144 pp.; 6 plates, 4 text-figures. 1920. Price 7*s.* 6*d.* net.

The Mesozoic Rocks of Applecross, Raasay and North-East Skye. By G. W. Lee, D.Sc., with contributions and an Appendix by S. S. Buckman, F.G.S. 93 pp.; 10 plates, 1 text-figure. 1920. Price 6*s.* net.

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APPENDIX I.

The Banffshire Coast Section of the Highland Schists.

By H. H. Read.

It is fortunate for the study of the Highland schists of North-East Scotland that, in the Banffshire Coast Section (Sheet 96), there is available what is probably the most continuous section of these rocks in the Highlands. This section (Fig. 2) is over 25 miles in length, with but a few trifling gaps, all of which can be filled by adjacent inland exposures. Except at a few localities, the cliffs are easily accessible and, together with the rocky foreshore, provide magnificent sections for study. The run of the coast line is west and east, almost at right angles to the strike of the Highland schists—a circumstance showing once more the exceptional nature of this section. Upon its interpretation must depend the interpretation of the somewhat poorly exposed Buchan, Strathbogie and Lower Banffshire districts of the North-East Highlands.

No modern work has been done on this section. Amongst the early workers are numbered Jameson,[1] Prestwich,[2] Hay Cunningham,[3] Harkness,[4] and Wallace.[5] The ground was originally mapped by Dr. John Horne, and his results were published in 1895 as the present One-inch Sheet 96 (Banff) of the Geological Survey Map of Scotland.

The lithological sequence of the Highland Schists of the Banffshire coast section from west to east is as follows :—

Keith Division	(*a*) Cullen Quartzite	a^1—Findochty Beds.
		a^2—Logie Head Beds.
	(*b*) West Sands Garnetiferous Mica-Schist.	
	(*c*) Findlater Flags.	
	(*d*) Crathie Point Calcareous Group.	
	(*e*) Garron Point Actinolitic Schists.	
	(*f*) Sandend (Black Schist-Limestone) Group.	
	(*g*) Durn Hill Quartzite.	
	(*h*) Portsoy Group.	
	(*j*) Cowhythe Gneiss.	
Banff Division	(*k*) Boyne Limestone.	
	(*l*) Whitehills Group.	
	(*m*) Boyndie Bay Group.	
	(*n*) Macduff Group.	

[1] Robert Jameson, 'Mineralogy of the Scottish Isles,' vol. ii, 1800, pp. 267–279.

[2] J. Prestwich, 'On the Structure of the neighbourhood of Gamrie, Banffshire,' *Trans. Geol. Soc.*, vol. v, 1840, p. 141.

[3] J. H. Cunningham, 'Geognostical Account of Banffshire,' *Trans. High. Agric. Soc., Scot.*, vol. xiv, 1843, pp. 447–502.

[4] R. Harkness, 'On the Metamorphic Rocks of the Banffshire Coast,' *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, pp. 331–336.

[5] T. D. Wallace, 'The Geology of Rathven and the Enzie,' *Trans. Edin. Geol. Soc.*, vol. iii, 1880, p. 331.

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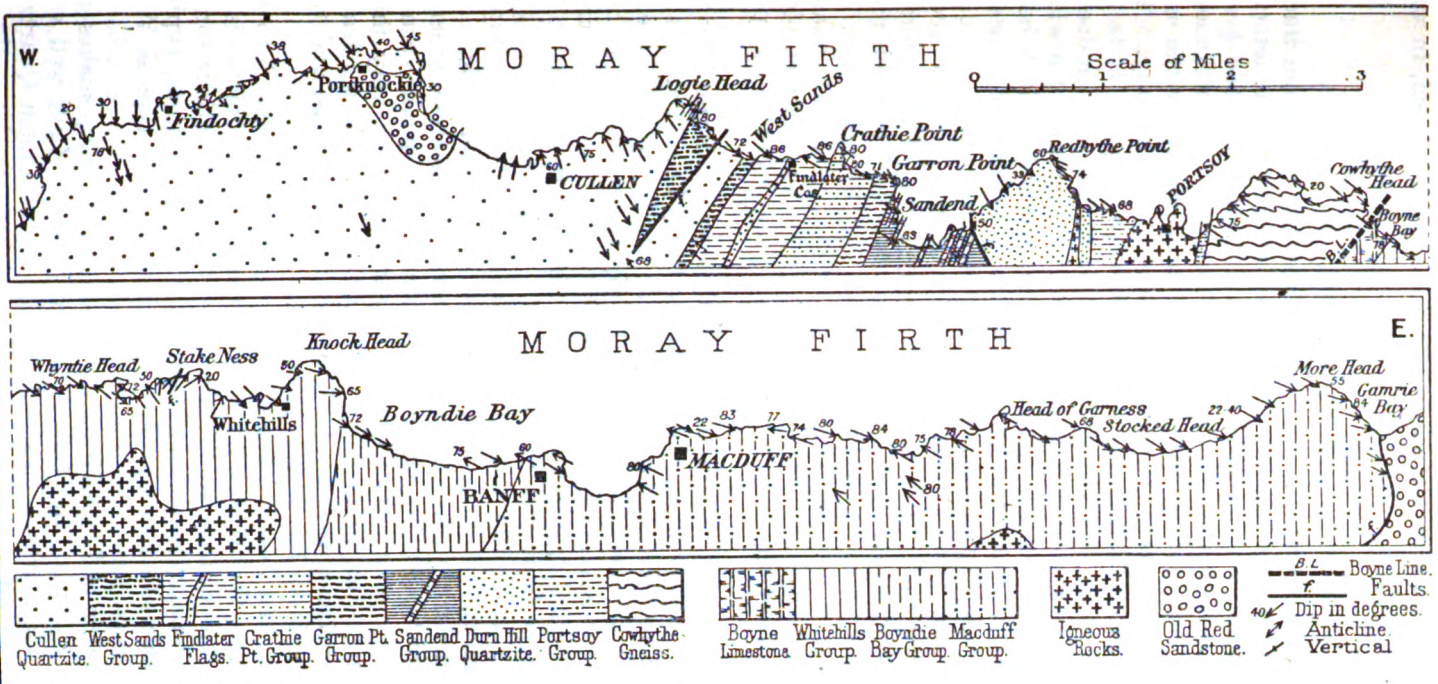

FIG. 2.—Geological Map of the Banffshire Coast.

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A short description of these groups will be given, and the reasons for the separation into two divisions developed, in what follows.

KEITH DIVISION.

(a) *Cullen Quartzite.*—This group forms the coast from Buckie eastwards to Logie Head, 1 mile east of Cullen. A detached area is found, with a breadth of 500 yds., at Sunnyside ¼ mile east of Logie Head. From Buckie eastwards to Portknockie, the coast runs parallel with the strike, and practically the same beds—the *Findochty Sub-group*, are seen all the way. The strike is about E.N.E.—W.S.W.; the prevailing dip is to the S.S.E., at rather low angles. The staple rock of the Findochty Sub-group is a very fine-grained granulitic quartzite of a white, grey or pinkish colour. The rock is massive and in thick beds; colour banding and the production of white mica in zones of intense folding have been noted. In slice, orthoclase is found to be almost always present in small amount in these rocks. Interbedded with the quartzite are many bands of dark, almost black, garnetiferous mica-schist; such bands seldom reach more than a foot or so in thickness, and are usually much less. In slice, these schists are composed of coarse, granulitic quartz, scarce orthoclase, abundant yellow-green to greenish-black biotite, scarcer muscovite and spongy porphyroblasts of pink garnet.

The remaining part of the Cullen Quartzite is formed by the *Logie Head Sub-group*. These rocks are thinly bedded and flaggy and point to the oncoming of the great flag groups to the east. The strike is about N.E.—S.W., the dip is vertical, or at high angles to the N.W. or S.E. The members of this sub-group are a rapidly alternating series of different kinds of rocks, each band averaging perhaps one or two feet in thickness. The highly crystalline granulitic quartzite of the Findochty Sub-group is still common, but here forms thinner bands. With these are associated dark, pinkish micaceous quartzites, mealy-weathering quartz-schists, buff quartzites speckled with small garnets, banded grey quartzites with thin micaceous layers, very finely banded grey and white flaggy beds with much silvery mica on the flag surfaces, very garnetiferous dark mica-schists, and thin bands of epidote-hornblende-granulite.

At the east head of Logie Head, a good transition into the next group—the West Sands garnetiferous mica-schists—is to be seen, the change taking place by the interstratification of granulitic quartzites and dark garnetiferous mica-schists, typical Cullen Quartzite rocks gradually giving place to typical West Sands schists.

Eastwards of Logie Head, the West Sands Group makes the coast for 500 yds., and then is faulted out by a fault well seen between tide marks. This fault brings on the Cullen Quartzite again for about 500 yds. until these rocks pass, by a similar

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transition phase, eastwards into the main outcrop of the West Sands Group at West Sands.

(b) *West Sands Garnetiferous Mica-Schist.*—At West Sands this group has an outcrop 120 yds. wide, with a high dip to the S.E. The group also forms the shore section for 500 yds. between the two outcrops of Cullen Quartzite, as already mentioned. In both places a gradual passage from Cullen Quartzite is seen; eastwards from West Sands, the West Sands Group passes gradually into the Findlater Flags. In West Sands, the staple rock of the group is a dark garnetiferous mica-schist, with quartzose bands and quartz kernels. In the centre of the outcrop there is a *calcareous* zone made up of thin, siliceous limestone bands, aggregating in all perhaps 2 or 3 ft. in thickness. In slice, the staple garnetiferous mica-schist is composed of two micas, quartz and garnet. The garnet forms porphyroblasts usually better shaped in the finer grained rocks.

(c) *The Findlater Flags.*—This group follows evenly eastwards from the West Sands Group and, by the incoming of calcareous material, it passes evenly into the Crathie Point Calcareous Group on its eastern margin. It forms the shore section for about 1,000 yds.; dips are high, usually to the S.E., but occasionally to the N.W. Throughout its outcrop, this group is composed of grey quartzose beds separated into flags by the development of mica on plane surfaces. Usually individual flags are about an inch or so in thickness. In slice, the typical flags are seen to be plane-foliated micaceous granulites composed of quartz and parallel plates of biotite and muscovite; the muscovite is occasionally set in large plates athwart the foliation. Garnet is seen in many slices. At Findlater Castle there is a narrow band of white, highly crystalline pure quartzite which, in slice, is seen to be composed of large sutured grains of quartz, with a very small quantity of white scaly mica.

(d) *The Crathie Point Calcareous Group.*—This group follows eastwards from the Findlater Flags, and forms the coast section between Crathie Point and Garron Point. Its width across the strike is about 570 yds.; dips are usually over 80°, and are predominantly towards the west. The main rock of the group is a pale, calcareous mica-schist, often weathering with a honeycombed yellow crust. In slice, this rock is a calc-biotite-schist, composed of about 75 per cent. calcite together with biotite, and quite subordinate quartz grains. With this calcareous flag type there are associated a few bands of very coarse, quartz-kernelled, kyanite-biotite-gneiss. Thin bands of garnet-staurolite-schist are also encountered. Towards its eastern margin, this group contains a few bands of actinolite-schist, which becomes the dominant rock in the succeeding Garron Point Group.

(e) *Garron Point Actinolitic Schists.*—This group follows evenly from the Crathie Point Group, and passes eastwards into the Sandend Group, in which rock-types characteristic of the Garron

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Point Group still persist. The width of the outcrop across strike is about 330 yds. The general dip is between 70° and 80°, and is either to the S.E. or N.W. The characteristic rock of this group is a dark, lustrous, poorly schistose rock in which there is a great development of blades of dark actinolite in felted masses, aggregates, or subradiate groupings.

Similar rocks occur at the eastern margin of the Crathie Point Group and throughout the Sandend Group, and show the essential unity of this part of the Keith Division. The actinolite-schists, unquestionably of sedimentary origin, represent the effect of regional metamorphism on an impure calcareous rock. In slice, they are composed of quartz, biotite and calcite as a ground-web, in which are set large porphyroblasts of pale green or almost colourless actinolite. With the actinolite-schists are associated flaggy micaceous quartzites and lustrous fine-grained dark grey schists with moiré surfaces.

(f) *The Sandend (Black Schist-Limestone) Group.*—This group is one of the most important stratigraphical divisions of the Highland Schists of this section. Its main rock types are black schist and limestone; stratigraphical groups characterised by these two rock types are known throughout the Highlands. On the coast the Sandend Group forms the shores of Sandend Bay and follows evenly from the Garron Point Group, but is faulted against the succeeding group on the east, that of the Durn Hill Quartzite. This fault runs N.W.–S.E., and a short distance inland what may be taken to be the full succession of the Sandend Group is found. The width of the fullest outcrop across strike is a little more than a mile; the dip is uniformly S.E. at angles of 66° to 80°. In the fullest succession there are seven broad belts of limestone, but whether these are distinct limestones or repetitions of one or more is not yet settled. A summary of the succession from the margin of the Garron Point Group eastwards is as follows :—(i) crushed good black schist with white limestone lenticles, 5 yds.; (ii) thick limestone, 17 yds.; (iii) calcareous flags, black schists, actinolite-schists and mica-schists, 170 yds.; (iv) limestone, 17 yds.; [gap of 365 yds.]; (v) limestone, 40 yds.; (vi) black schist, 230 yds.; (vii) limestone, 60 yds.; (viii) black schist, 22 yds.; (ix) limestone, 120 yds.; (x) black schist, 2 yds.; (xi) limestone, 90 yds., faulted against Durn Hill Quartzite. To this section may be added, from inland exposures in the Burn of Fordyce, the following items :—(xii) black schist with staurolite, 372 yds.; (xiii) limestone, 150 yds.; (xiv) black schist with staurolite, 230 yds., up to the approximate edge of the Durn Hill Quartzite.

(g) *Durn Hill Quartzite.*—This group takes its name from Durn Hill, 2 miles S.W. of Portsoy; it occurs on the coast at Redhythe Point between Sandend and Portsoy. The width of its coastal outcrop across strike is perhaps a mile; dips are steep and variable; the strike varies between N.E.–S.W. and N.–S. The group is faulted, on the coast, against the Sandend Group

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as has already been pointed out, but eastwards it passes into the Portsoy Group. Inland, this quartzite is at present considered to be conformable to its neighbours. The rocks of this group are more impure, more massive, less flaggy and less alternating than those forming the Cullen Quartzite already described. The most quartzose type is a felspathic quartzite composed of quartz, orthoclase, acid plagioclase and microcline, and micas. With this type are associated mica-quartz-gneisses, sillimanite-gneisses, flaggy micaceous quartzites and garnetiferous mica-schists, the last three rocks being of restricted occurrence.

(h) *Portsoy Group.*—This group occurs on both sides of Portsoy and follows on eastwards from the Durn Hill Quartzite. Its outcrop is about one mile across strike, but over half of this breadth is occupied by the sill-like mass of Older Igneous Rocks comprising serpentinised pyroxenite and peridotite, anorthosite, gabbro, enstatite-gabbro, epidiorite, amphibolite, gabbro-schist, hornblende-schist and hornblende-granulite, of which a summary has been given elsewhere.[1]

The sediments of the Portsoy Group are varied. A traverse eastwards from the east edge of the Durn Hill Quartzite shows the following succession. For 400 yds. the rocks are dark corrugated mica-schists, often silvery and garnetiferous: in this series are three narrow zones of graphite-schist. The dip hereabouts is E.S.E. or S.E. at 50°–70°. Eastwards of this belt and occupying the shore for over 100 yds. there is a very varied, rapidly alternating, group of banded calcareous flags and abundant tremolite-limestones, followed by chiastolite-staurolite-schist, dark calcareous flags, limestones and quartzose calcareous flags till the western edge of the igneous rocks is reached. Amphibolite and serpentine now form the shore for over 100 yds. Then, for about another 100 yds., a varied series of sugary white quartzite, dark mica-schist, white calcareous flags and white limestone is found before the western edge of the main mass of igneous rocks is reached. The igneous rocks form the coast about Portsoy Harbour, and include blocks of wollastonite-rock in them. The sediments, where next seen on the east shore of Links Bay, are crumpled and corrugated limy flags, impure limestones and dark mica-schists which soon pass eastwards into the next group, the Cowhythe Gneiss.

Superficially the Portsoy Group is like the Sandend Group, but when the two groups are mapped in detail, it is seen that there is really very little similarity between them.

(j) *Cowhythe Gneiss.*—This well-marked group forms the coast from Links Bay eastwards almost to the Boyne Burn. Across strike its width is a little over a mile. It follows evenly eastwards from the Portsoy Group, but is separated from the first member of the Banff Division, namely, the Boyne Limestone, by a line of

[1] H. H. Read, *Geol. Mag.*, 1919, p. 364; 'Summary of Progress for 1918' (*Mem. Geol. Surv.*), 1919, p. 26.

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disruption which may be called the *Boyne Line*. Throughout its extent the Cowhythe Gneiss is a dark, gnarled coarse biotite-gneiss with subordinate finer mica-schist bands; throughout kernels, stringers and bands of quartz are very common. In slice, the typical gneiss is composed of quartz, acid plagioclase, biotite and muscovite, occasionally with sillimanite, cordierite and tourmaline. At a point 300 yds. from its western edge, there is a calcareous horizon with about 10 ft. of white limestone, which may be called the Rosehall Croft Limestone. At the Boyne Line, the Boyne Limestone is composed of thin limestone and purplish phyllites. As these rocks are followed in towards the margin of a nose of good Cowhythe Gneiss, they are seen to be drawn out and finally to disappear against the gneiss. All around there is much brecciation and slickensiding of the rocks. A short account of the phenomena along the Boyne Line as it is traced inland will be given in a later page.

Banff Division.

(k) *Boyne Limestone.*—Eastwards of the Boyne Line, the Boyne Limestone is seen around Craig of Boyne and Boyne Bay. From the Boyne Line eastwards for perhaps 140 yds., the rocks are thin limestones, purple phyllites and banded mica-schists with quartz kernels. Several fault breccias are seen hereabouts. Eastwards follows the thick mass of Boyne Limestone, which has a width across strike of about 300 yds. This limestone is grey, blue or white, with thin intercalations of more impure material and with nests and kernels of quartz. It is violently folded and crumpled.

(l) *Whitehills Group.*—The Boyne Limestone passes eastward into this group by the incoming of purplish phyllites and the gradual disappearance of limy bands. The Whitehills Group forms the coast for three miles, and is linked on the west to the Boyne Limestone and on the east to the Boyndie Bay Group. It is a very flaggy group made up of rapid alternations of its several members. These are banded flaggy quartzites, compact fine-grained limestones, coarse gritty limestones, calcareous flags, purplish phyllites and pebbly grits with large pebbles of quartz and pink felspar. In addition, there are a few bands of nodular andalusite-mica-schist, which become more common towards the east till the next group is reached, in which they are the predominant rock type. On the whole, it may be stated that the pebbly limestones are confined to the western and central parts of the outcrop, the coarse pebbly grits and andalusite-schists to the eastern part. On Knock Head, there is a great development of coarse pebbly grit with pebbles, occasionally composite, but more often of either quartz or pink felspar, which may reach an inch or more in diameter. Several broad sills of amphibolite are found in this group about Whyntie Head.

(m) *Boyndie Bay Group.*—This group is seen in Boyndie Bay to the west of Banff. Throughout it there occur bands of pebbly

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quartz-felspar-grit like those already mentioned from the preceding group. The main rock is, however, a slaty rock, characterised by the gradual development of andalusite from a rudimentary to a complete form. The western edge of the group is characterised by silvery rocks studded with large crystals of andalusite; these are followed eastwards by rocks with elongated knots of andalusite, and these, still further east, by spotted slates which, in turn, give place to the unspotted slates of the next group. Whatever the cause of this development of andalusite, it is apparent that its effects increase in intensity from east to west.

(n) *Macduff Group.*—This great group occupies the remainder of the coast section here described, and is well exposed for a distance of 9 miles eastwards from Banff. The beds are thrown into a rapid series of steep-sided folds; but, even so, this group is probably of very great thickness. Strikes are between E.N.E.–W.S.W. and N.E.–S.W. The main rock of the group is a blue or green slate which has been worked for roofing slate at various points. With this occur in subordinate amount, pebbly quartz-felspar-grits, fine-grained grey and white grits, and fine blue greywackes.

There can be no doubt that the four members of the Banff Division form a natural stratigraphical sequence; they are linked together by transitions and by a thorough community of rock types.

It has now been shown that the Highland schists of the Banffshire coast section fall into two great divisions, separated by the line of disruption described as the Boyne Line. To the west of the Boyne Line there is the Keith Division, composed of rock types which are probably the continuation of Central Highland rocks. The Keith Division is thoroughly metamorphic in character; schists and gneisses represent the pelitic facies of the original sediments; chief among the metamorphic minerals are garnet, staurolite, kyanite and sillimanite. Eastwards of the Boyne Line is the Banff Division of which a few types recall some of those of the Loch Awe district of the S.W. Highlands. This division is much less highly metamorphosed; phyllites, rather than mica-schists, predominate in the more highly-metamorphosed parts; slates and clastic sediments are widespread; andalusite is the characteristic metamorphic mineral of this division.

If the ideas of metamorphic zones conditioned by depth of burial, advanced by C. Van Hise, F. Becke, U. Grubenmann and others, are to be accepted, then it follows that the Banff Division is structurally above the Keith Division. Further, the Macduff slates must be structurally the highest member of the Banff Division.

The phenomena along what may be considered the inland extension of the Boyne Line are not without interest. The thick

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Boyne Limestone (the thickest limestone of this section) can be followed southwards for less than 2 miles. Southwards, again, the Cowhythe Gneiss is adjacent to the Whitehills Group. Still further south, both the Cowhythe Gneiss and the Whitehills Group vanish, and in the ground to the S.W. of Huntly the Portsoy Group comes against the pebbly grits and andalusite-schists of the Boyndie Bay Group. It seems possible, therefore, that this line of disruption that has been found at the Boyne on the coast may be an important tectonic feature in the architecture of the Highland Schists of N.E. Scotland. The complete elucidation of the Boyne Line can only be obtained by the detailed study of the Buchan, Formartine, Alford and Strathdon districts of Aberdeenshire—a study which has not yet been attempted.

The Banffshire Coast Section in relation to the Highland schists of other parts of Scotland.—The chief point of interest following from this study of the Banffshire rocks seems to be their separation into two divisions. There appears to be little doubt that one of these—the *Keith Division*—represents the northern continuation of the Perthshire Schists described by Mr. George Barrow, Mr. Cunningham Craig and others, in the Memoirs on Sheets 55, 65 and 64. There seem to be very large questions still to be settled in the Perthshire ground and, until some agreement has been reached as to the stratigraphical sequence in this area, it is a hazardous proceeding to attempt any thorough correlation.

It has been shown that, in Banffshire, there are two quartzites, of which one, the Cullen Quartzite, contains rock types in a Moine state. The Cullen Quartzite is undoubtedly that seen at Ben Aigan on Speyside (Sheet 85), and the Ben Aigan Quartzite appears to be continued south by a belt of quartzite at the edge of the Moines to Inchrory in Sheet 75. South of this, the cordon of the Cairngorm, Lochnagar and Hill of Fare Granites sweeps right across the path of the Keith Division. Two quartzites, so far as I know, have not been recognised in Perthshire. There is every reason to believe that the second Banffshire Quartzite, that of the Durn Hill, is the Central Highland Quartzite of Perthshire. I hold, at present, that the Durn Hill Quartzite is conformable to its neighbours and is interstratified in the Keith Division. The relations of the Central Highland Quartzite in Perthshire are the subject of dispute.

Another fairly sure step may be made. The Sandend (Black Schist-Limestone) Group, occurring on the west side of the Durn Hill Quartzite, appears to be equivalent to the Blair Atholl (Black Schist-Limestone) Group occurring on the west side of the Central Highland Quartzite. Lithologically they are the same.

The Findlater Flags, Crathie Point Group and Garron Point Group resemble the Parallel Banded Series (Hones) and Tremolite-

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Limestone of Perthshire, and it is possible that this correlation will hold.

It has been shown that, in Banffshire, the rocks on the opposite sides of the Durn Hill Quartzite are, while somewhat similar, two distinct rock groups, those of Sandend and Portsoy. From what can be made out of the complicated and, in part, controversial description of the Perthshire ground, it appears that this independence of the two 'dark schist and limestone' groups on opposite sides of the Central Highland Quartzite has not always been recognised. In agreement, I believe, with Mr. George Barrow, I am inclined to correlate, after a short visit to the Perthshire ground, the Portsoy Group with the zone of thin limestone and dark schist seen on the south-east side of the Central Highland Quartzite on Farragon Hill and Beinn Eagach, and beside the Tummel opposite Faskally House. In the published map of this ground (Sheet 55), this Beinn Eagach group is shown as running into the Blair Atholl group on Meall Uaine, north of Pitlochry. This, from my Banffshire experience, I consider to be extremely unlikely.

To the south-east of the Beinn Eagach Group of Perthshire, there occur the Ben Lawers Schists (= Calc-sericite of Central Perthshire = Caenlochan Schists of Forfarshire, *fide* Mr. G. Barrow). These are possibly represented in Banffshire by the Cowhythe Gneiss.

No representative of the Schichallion Boulder Bed has yet been found in Lower Banffshire. It is known in Upper Banffshire at Meikle Fergie Burn, opposite Gaulrig, south of Tomintoul.

The following table of quite tentative correlations may be constructed :—

Banffshire.	Perthshire.
—	Loch Tay Limestone
—	Garnetiferous Mica-Schist
Cowhythe Gneiss	Ben Lawers Schists
Portsoy Group	Beinn Eagach Group
Durn Hill Quartzite	Central Highland Quartzite
Sandend Group	Blair Atholl Group
Garron Point Group, Crathie Point Group	Tremolite-Limestone
Findlater Flags	Parallel Banded Rocks or Hones
West Sands Group	—
Cullen Quartzite	—

The *Banff Division*, with its great development of slates, pebbly grits and gritty limestones, appears to be absent in Perthshire; this division is probably confined to Lower Banffshire, Strathbogie, Cabrach, the Howe of Alford, and Buchan. A few of its rock types, notably the pebbly quartz-felspar-grits and the gritty limestones, are lithologically similar to types occurring in the Loch Awe region of the South-west Highlands. Further, the state of metamorphism is low in both areas. No

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definite correlation between the Banff Division and the Loch Awe Group is advanced here; the above suggestions, however, are to be borne in mind in any further investigation of the North-East Highlands. By the development of research in the South-West Highlands, it is possible that some light will be thrown on the problems of the Banff Division, and in particular with regard to the significance of the Boyne Line and the resemblances of this division to the Loch Awe Group.

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APPENDIX II.

Report on Sections exposed in Excavations for Sewers in the Parish of Brockenhurst, Hants.

By H. J. Osborne White, F.G.S.

1. Introduction.

The construction of the Brockenhurst Sewer-System was undertaken for the Lymington Rural District Council by Messrs. Grounds and Newton, Contractors, of Richmond Chambers, Bournemouth, according to plans prepared by Messrs. Shanton and Easdale, Engineers, of No. 28, Victoria Street, Westminster.

Begun at the lower, or Disposal-Sump, end in 1914, and discontinued during the late war, the work was resumed in the autumn of 1919, and completed, as far as excavation was concerned, by the end of December, 1920. (The full drainage-scheme includes connections with Setley, Brockenhurst Weirs, and other outlying or detached settlements, but the construction of these branches has not yet been sanctioned.)

At the request of the Director of the Geological Survey (Sir Aubrey Strahan), the author of this Report made a preliminary inspection of the ground within the area of the Sewer System on the 9th–10th July 1920, and subsequently revisited Brockenhurst on eleven occasions, between the latter date and the 1st January 1921, with the object of compiling a record, and collecting specimens, of the strata exposed in the sewer-trenches opened under the then-existing contracts with the District Council. Opportunity was taken to inspect a number of pits in the Headon Beds, near Brockenhurst, all of which were found to be in worse condition than they had been six or seven years before; and a visit was paid to parts of the Barton coast-section having a direct bearing on the stratigraphy of the Sewer area.

The writer is under an obligation to Mr. W. Faber Elliot, the Resident Engineer, for ready assistance in the examination of the Sewer works and plans, as well as for periodical communications relating to the progress of the trenching and the nature of the ground in course of excavation.

2. Geological and other Formations Exposed.

Barton Sand.—To judge by their lie and character, the oldest strata trenched belong to the uppermost 20 ft. of the Becton Bunny Beds, or middle stage of the Barton Sand, as developed in the cliffs of Christchurch Bay. They consist of evenly-bedded, fine-grained, ferrous, micaceous, muddy sands; of blue-grey tint in the deeper sections and in those below local stream-level;

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dark-yellow, orange, or brownish-red where weathered. Their junction with overlying permeable beds, whether of Barton or later age, is commonly marked by a band of orange coloration, which is fairly constant in width, as if pertaining to a definite stratum, where the cover is part of the Barton Series.

The succeeding Long Mead End Sands (about 15 ft. thick) also are fine-grained and micaceous, but contain much less argillaceous and ferruginous matter, and are normally loose and light-tinted; pale greys and yellows predominating. Near their upper limit, however, they become rather loamy and greenish-grey, owing to the introduction of green mud like that prevailing in the Lower Headon Beds above, and include thin seams of a more positively argillaceous nature. At the Sewage Disposal Works, by Haze Farm, a light-green loamy sand, inferred to lie immediately below the Headon Beds, contains marcasite-concretions; some of irregularly lenticular shape, following the lamination of the sand; others sub-cylindrical, and disposed at various angles thereto. The scanty and ill-preserved organic remains observed in the Barton Sand of the Sewer area occurred as casts (wood, *Cyrena sp.*, *Psammotea* ?) in the lenticular concretions.

Lower Headon Beds.—The lateral variation to which the members of this freshwater series are subject was apparent in the Brockenhurst trenches.

The well-marked bottom-bed, which rests evenly on the Barton Sand, normally consists of a few inches of black, dark-grey, or soot-coloured carbonaceous silty clay to loam; partly laminate or shaly; partly (where the silt element predominates) of confused, flocculate structure. When weathered, it assumes the colour and appearance of moulded chocolate, and, in the majority of the trench-exposures, this facies only was presented. In at least two sections of the Headon-Barton contact, in the southern part of the Sewer area, the bed in question was missing.

In the neighbourhood of the Railway Station, the bottom-bed is succeeded by a white to pale greyish and greenish clayey silt, mottled rusty-brown, and resembling marl, but free from calcium carbonate. Similar deposits occur at the same horizon at and about the Disposal Works, half a mile to the north-east, and at Lymington, 4 miles to the south. In the southern part of the Sewer area, however, a bright-green clay with red mottling takes the place of the pale silt, which is either absent from the lower portion of the Headon succession, or—as in one observed instance—is developed at a slightly higher horizon.

Next follows light-green to greyish-green tough clay; pure, or with silty inclusions, in the lower part, and becoming arenaceous upward through the introduction of fine white quartz-sand, which occurs chiefly in little nests and thin partings. The succeeding beds of this Series, as far as seen, are light-greenish and greyish distinctly-sandy clays and clayey-sands.

No fossils could be found, either in the trenches or on the rain-washed heaps of excavated material. Save for a little

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granular race, the visible parts of the beds had been decalcified. The maximum thickness of Headon Beds exposed was about 20 ft. It was hoped that the interesting basal ('Brockenhurst') beds of the Middle Headon, which approach to within that number of feet of the Barton Sand under Ladycross Lodge, 2 miles eastward, would be encountered in the trenches near the Railway, but nothing resembling them, or suggesting deposition under marine conditions, was forthcoming.

Valley Gravel.—The bulk of this is typical river-gravel, of fine to medium texture, sandy, clearly stratified and current-bedded. Approximately 99 per cent. of the stones are sub-angular flints; the residue is made up of flint pebbles, sub-angular Selbornian cherty sandstone, pebbles of vein-quartz, &c., all most probably derived from the Plateau Gravel of the basin of Lymington River. The sand mingled with the stones, and occurring separately in seams and lenticular banks intercalated in the gravel, is mostly of light tints, and resembles that of the highest beds of the Barton Sand. In places, beds of reconstructed dark bluish-grey (Becton Bunny) sand were met with, one of which (at Waters Green) contains remains of plants. Masses of green clay and pale silt detached from the Headon Beds are not uncommon near the boundary of that formation. Cementation of the gravel, by iron peroxide and calcareous tufa, occurs sporadically and on a small scale. The greater part of the Valley Gravel within the Sewer area is disposed in gently-inclined sheets, rising from beneath the Recent Alluvium to a height of about 20 ft. above the neighbouring streams.

Trail.—In many places the Tertiary formations and the Valley Gravel are covered by from 1 to 5 ft. of stony or gravelly loam and sandy clay, largely composed, and containing incompletely assimilated bodies, of Headon clay and sand, Barton sand, and Plateau or Valley gravel; and commonly possessing a rude flow-structure, which was well displayed in the wet, clean-cut sides of the sewer-trenches. The bottom of the deposit is markedly uneven, especially on sand and gravel, into which it descends in vertical and oblique pockets. While this pocketing —and the contortion-phenomena often associated with it—may be due in a great measure to repeated intrusion, expansion and decay of tree-roots under present-day conditions, the trail itself is most probably the outcome of exceptionally active solifluction, under bygone conditions inimical to forest vegetation.

By the progressive blending of its varied constituents, the trail passes into impure brickearth. About Brockenhurst the trail is of no little importance agriculturally, inasmuch as it masks a good deal of stiff Headon clay, and affords a retentive soil for grass and arable-land over tracts of normally barren sand and gravel.

Alluvium.—This comprises peat, sandy flood-loam (brown and of open texture near the surface; greyish and more compact below), and parts of the low-level Valley Gravel rearranged by

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the streams in Recent times. Thin peat and peaty earth or sand, occupying slight hollows in the flood-loam and Valley Gravel, were intersected by the trenches at Culverley Green and south-west of Brockenhurst Bridge. In the first-named locality, sand and gravel, containing much peaty matter and drift-wood were met with a few feet beneath the bed of the brook.

Made Ground.—Except in the railway-embankments and causeways, and above culverts and water-mains, the made ground cut by the sewer-trenches was of moderate or trifling thickness, and generally consisted of road-metalling. The writer neither saw, nor could hear of the discovery of, any objects of archaeological interest. The early settlement of Brockenhurst presumably lay on the spur of comparatively high ground supporting the Parish Church, outside the area of the sewer-system.

3. Rectification of the Geological Survey Map.

The boundaries of the Solid formations and of the Valley Gravel about Brockenhurst are so obscured as to render their accurate mapping impossible, without the aid of the boring-tool, or of an adventitious series of cross-sections, such as those afforded by the main-drainage works.

At Balmer Lawn, the boundary of the Headon Beds lies a little to the west of the line assigned to it in the current Geological Survey Map on the 1-in. and 6-in. scales; while in the tract between the grounds of Careys (formerly 'Brockenhurst Lodge') and Brockenhurst Weirs, it lies in places nearly half a mile south-east of that line. In the latter area, a thin spread of trail is responsible for the misleading occurrence of soils and vegetation appropriate to the Headon Beds on a low-lying portion of the Barton Sand outcrop. The Headon Beds hereabouts come on in a slight rise, which begins to be noticeable some 150 to 200 yds. north-west of, and 10 to 15 ft. below, their boundary.

The Valley Gravel proves to extend farther southward of the Lymington River than has been supposed, and to occur in considerable thickness within a few yards of its southern limit near the middle of the village. Boundary features are faint or wanting, much of the ground having been smoothly graded before and during the formation of the trail.

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APPENDIX III.

On Borings for Coal near Maryport, Cumberland.

By Bernard Smith, M.A.

Two boreholes have been put down recently, by the Cumberland Coal, Power and Chemicals, Ltd., to test the Coal Measures concealed beneath the New Red Sandstone near Maryport, on the northern side of the so-called 'Boundary Fault' of the Cumberland coalfield.

Near Maryport, at least, it was expected that higher Coal Measures would have been present than in the exposed field south of the fault; in fact, the Boundary Fault had previously been driven through in the Ten Quarters Coal at Ellenborough Colliery,[1] and Whitehaven Sandstone was said to have been entered on the north side, and to prove a great downthrow in that direction, corresponding with the downthrow observed in the Triassic Rocks.

The strata penetrated by these bores, however, did not support this view, and, moreover, did not appear to correlate with anything known in this part of the county. At the invitation of the Company the cores were first examined in detail in May 1920, and permission to publish the results has been given freely by Messrs. A. E. Barton and H. E. P. Cottrell, Directors of the Company. Our thanks are also due to Major J. G. Scoular of Oughterside Colliery, under whose supervision the borings were made.

Bank End Boring (Fig. 3).

This boring is situated close to the cemetery, 1½ miles N.N.E. of Maryport, on the west side of the road to the coast. One-in. New Series Ordnance Map, Sheet 22; Old Series Geological, 101 N.W.; 6-in. Cumb. 45 N.W. Lat. 54° 43′ 55″, Long. 3° 28′ 25″. Height of surface above O.D. 27 feet.

The boring was executed by the Sullivan Machinery Co., U.S.A. Commenced November 1919 and completed May 1920. The cores were 2-in. diam. throughout. The dip in the St. Bees Sandstone is low; in the Coal Measures it varies from about 10° to 18°, and in the Carboniferous Limestone Series from 13° in shales (1,826 ft.) to as much as 30° or 35° (1,707 ft.) in laminated sandstones.

The journal of the boring is printed in slightly condensed form as it was received from the engineers, but descriptive notes, in square brackets, have been added after examination of the cores.

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[1] 'Final Report of Royal Commission on Coal Supplies,' 1905, pt. ix., p. 17.

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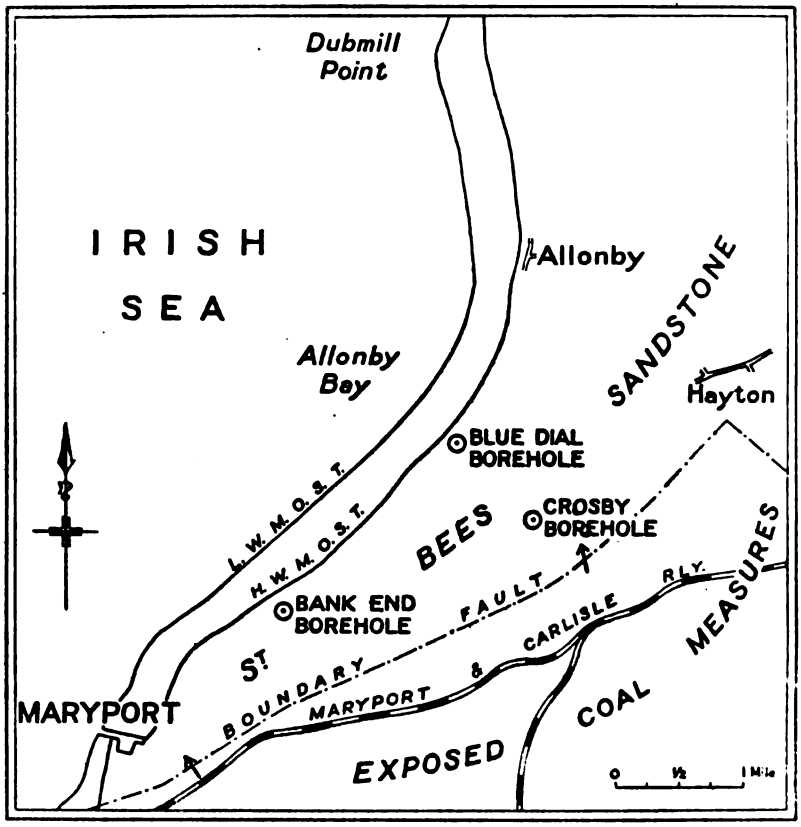

FIG. 3.—Sites of Borings near Maryport.

	Thickness. Ft.	in.	Depth. Ft.	in.
GLACIAL :—				
Gravel, clay and sandy clay	34	0	34	0
ST. BEES SANDSTONE :—				
Red sandstone, with bands of red marl and shale: thin bands of gypsum between 283 and 493 ft. [sandstones with greenish-grey bands at intervals: the chocolate-red shales are micaceous in places]	510	6	544	6
[Breccia] Base of sandstone with small marl pebbles, &c. Red and green marls churned together Fragments of Coal Measure shales, &c.	3	0	547	6
LOWER COAL MEASURES :—				
Rough red shale, variegated [purplish fine-grained shales and sandstones, with occasional concretions of hæmatite]	23	8	571	2
Very dark shale		4	571	6
BONE COAL [sandstone and coal mixed]	1	7	573	1
Grey sandy shale [with rootlets in upper part, on shales with ironstone balls]	10	11	584	0
Dark shale and metal [grey mud-stones with rootlets]	3	3	587	3

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	Thickness. Ft.	in.	Depth. Ft.	in.
COAL [poor and pyritous]		7	587	10
Hard grey shale	2	2	590	0
Sandy shale	6	0	596	0
Blue metal [grey and blackish mudstone with rootlets, pinnules and shells. Ironstone at 600 ft. 1 in.]	11	0	607	0
Red and dark shale, mixed	2	0	609	0
Red and grey shale [micaceous sandstone at base: spar joints]	5	0	614	0
Red sandy shale	6	0	620	0
Dark grey shale [mudstone with rootlets]	6	0	626	0
Very dark shale [with rootlets and shells]	11	5	637	5
BONE COAL with spar [and copper-pyrites]	1	1	638	6
Hard fireclay [mudstone with rootlets]	4	6	643	0
Fireclay [fine-grained, dark grey sandstone]	1	0	644	0
Grey beds and mixed sandy shale [red and black]	23	0	667	0
Light-brown sandstone [pinkish: micaceous near base]	39	0	706	0
Dark shale with variegated sandstone bands [dark and red sandy shales, both with black mica]	13	0	719	0
Dark shale [plants and shells]	2	5	721	5
BONE COAL	1	1	722	6
Fireclay [fireclay 2 ft., on sandy shale and sandstone]	7	6	730	0
Grey sandstone	3	0	733	0
Dark shale [with plants, shells and ironstone]	24	0	757	0
Black metal [smooth black shales with fossils]	1	11	758	11
COAL [poor]	2	3	761	2
Fireclay [and sandstone]	1	10	763	0
Sandy grey shale [chiefly white sandstone]	5	0	768	0
Dark shales, with ironstone [fossils]	9	3	777	3
COAL, traces of spar and sulphur [pyrites]	1	6	778	9
Fireclay	1	3	780	0
Dark grey shale [some fireclay]	18	0	798	0
Dark shale [shale and sandstone: plants]	24	4	822	4
COAL [with 3-in. roof of black shale]		11	823	3
Fireclay	2	9	826	0
Dark shales [and shaly sandstone]		10	826	10
COAL		1	826	11
Fireclay [brown and sandy]	2	1	829	0
Dark shale and grey bed [with current-bedded sandstones, and plants]	30	0	859	0
White sandstone on dark shale [plants]	10	0	869	0
Fireclay with ironstone bands near base	4	6	873	6
Grey sandstone	25	9	899	3
Dark shale [black: ironstone balls, and fish remains]	9	3	908	6
Fireclay [pulped shale on black shale]	2	0	910	6
COAL [poor]	1	9	912	3
Fireclay	2	9	915	0
Sandy shale	16	0	931	0
Fireclay [grey shale, on 18 in. fireclay]	5	0	936	0
Sandy shale and grey bed [1 ft. fireclay: plants]	15	0	951	0
Sandy and dark shales [soft black and micaceous: shells and plants]	25	10	976	10
COAL [core missing]		5	977	3
Dark shale [plants and ironstone]	6	9	984	0

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	Thickness. Ft.	in.	Depth. Ft.	in.
Coal [poor, with calcite joints]		8	984	8
Fireclay	1	4	986	0
Dark shales [mudstone with ironstone]	5	2	991	2
Coal [poor]		11	992	1
Fireclay	1	11	994	0
White sandstone	27	0	1,021	0
Fireclay and dark shale	5	0	1,026	0
Carboniferous Limestone Series :—				
Dark shales with shells and spar bands [crinoids and marine shells]	1	0	1,027	0
Sandy shales [white sandstone with dark shale and coaly layers]	4	0	1,031	0
Dark shales	1	0	1,032	0
Hard fireclay [shaly at top]	5	0	1,037	0
Fireclay [greenish shale]	3	0	1,040	0
Dark shale [shales and mudstones; ferrous carbonate and pyrites]	10	0	1,050	0
Dark shale	10	0	1,060	0
Dark brown shale [fossiliferous]	9	0	1,069	0
Grey bed, hard post and sandstone [whitish quartzose sandstone, with black mica, and 1 foot shale]	36	0	1,105	0
Dark shale with ironstone nodules and few shells	4	0	1,109	0
Hard dark shale [fossiliferous]	16	0	1,125	0
Dark firelay [smooth micaceous shale and bastard cannel]		8	1,125	8
Coal, very dirty [full of calcite]		4	1,126	0
Fireclay	1	6	1,127	6
Very coarse grey bed [sandstone and shales]	18	6	1,146	0
Dark shale with ironstone, pyrites and crinoids, on sandstone and shale : limestone at 1,171 ft.]	30	0	1,176	0
Sandstones and sandy shales [fossiliferous]	139	0	1,315	0
Red sandstone [pink, purple and white : micaceous]	13	0	1,328	0
Fireclay [dark grey, black and purple : micaceous]	2	0	1,330	0
Grey bed [20 ft.], on sandstone	48	0	1,378	0
Dark grey sandy shales [black mica and plants]	4	0	1,382	0
Grey bed, separated by sandstone, 4 ft. [plants]	23	6	1,405	6
Black shale [shells and plants]	12	0	1,417	6
Hard dark shales [dull sandy shales, calcareous in places : highly fossiliferous. *Reddish limestone* at 1,425 feet]	44	0	1,461	6
Red, on white, sandstone [white, pink and red, micaceous and with shales]	16	6	1,478	0
Black shale [mixed with sandstone : plants]	12	0	1,490	0
Dark black, sometimes sandy, shales and grey bed [pyrites nodules and traces of plants]	35	0	1,525	0
White sandstone [purplish in places : coaly layers]	13	9	1,538	9
Dark shale with 1 in. Coal		3	1,539	0
Grey bed and white sandstone, mixed	17	9	1,556	9
Coal		6	1,557	3
Brown shale		3	1,557	6
Fireclay [black, with rootlets]	3	0	1,560	6
Sandstone and grey bed	16	6	1,577	0
Dark shales, grey beds and sandy shales [plants, crinoids and shells from 1,636–1,637 ft.]	79	0	1,656	0
White sandstone	12	0	1,668	0
Dark shale and grey bed	27	6	1,695	6
Broken dark shale [1,697–1,698 ft., dark shale on black shale with *Lingula*]	3	6	1,699	0

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Coal—*continued.*	Thickness. Ft.	in.	Depth. Ft.	in.
Sandstones and grey beds, some red	37	0	1,736	0
Grey bed and dark shales	65	0	1,801	0
Sandstones, grey beds and shales [fossils at 1,826–7 ft.]	96	0	1,897	0
Grey and white sandstone	24	6	1,921	6
Dark shale [with sandstone: fossils at 1,954 ft. 6 in. in ferrous carbonate]	63	6	1,985	0
Grey bed, sandstone and shale with spar	14	0	1,999	0
Dark shales and sandstones, mixed	75	0	2,074	0
White sandstones and grey beds	157	0	2,231	0
Coal		4	2,231	4
Shale, sandstone and grey bed	64	8	2,296	0
Coal		4	2,296	4
Dark shale, grey beds, sandstones and shales	250	8	2,547	0
Coal		3	2,547	3
Shale and sandstone	36	3	2,583	6
Coal, small pieces	1	10	2,585	4
Sandstone, grey bed and shale	62	8	2,648	0

Blue Dial Boring (Fig. 3).

This boring is, in its essentials, similar to the above, but was finished at a slightly later date. It is situated close to the coast-line nearly 2 miles N.E. of the Bank End boring and about 200 yds. S.W. of Blue Dial. Six-in. Cumb. 35 S.W. Lat. 54° 45′ 9″, Long. 3° 26′ 25″.

Height of surface above O.D. 21 ft.

The dip of the lower series is in places as high as 30°.

A summary of the chief divisions is as follows:—

	Thickness. Ft.	in.	Depth. Ft.	in.
Glacial	46	6	46	6
St. Bees Sandstone, with 3-in. breccia at base	664	6	711	0
Lower Coal Measures, stained red and purple to about 880 ft., with 13 thin coals	951	0	1,662	0
Carboniferous Limestone Series, with coal and shale parting at from 2,043 ft. 8 in. to 2,045 ft. 8 in.	673	0	2,335	0

The breccia at the base of the Trias in this boring consisted of small pellets of New Red Marl and Sandstone in sandstone, on small fragments of Coal Measure shales. There was also a thin layer of fibrous gypsum close above the breccia. The junction was difficult to detect owing to the staining of the underlying Coal Measures.

The base of the Coal Measures in each boring has been fixed at a point below which there is the first appearance of crinoidal and shell-bearing shales of marine type. Lithologically, however, apart from some thin bands of limestone, calcareous shales, or calcareous sandstone, the lower series bears a resemblance to the Coal Measures. Bands and balls of ferrous carbonate and pyrites occur in both, and certain shales and sandstones contain black mica. Plant remains also occur in both. There is no sign of unconformity at the junction in either section.

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The 'grey-beds' are usually alternations or admixtures of sandstone and shale.

The Coal Measures contain no coals that can be recognised in neighbouring collieries and none appears to be of value. The coals in the underlying beds are apparently placed for the first time at their proper horizon, although they may have been bored through or may crop out in the district.

The fossils given below have been examined and named by Mr. J. Pringle and Dr. Robert Kidston, F.R.S.

LIST OF FOSSILS FROM BANK END BOREHOLE, MARYPORT, CUMBERLAND (B.S. 1439–1803).

	Depth in Feet.
Mariopteris muricata (*Schloth.*)	802–807
Neuropteris heterophylla *Brongn.*	735–744
,, *cf.* ,,	566, 570
,, tenuifolia (*Schloth.*)	818–820
,, *cf.* ,,	802–807
,, sp.	802–807, 818–820
Sphenopteris *cf.* obtusiloba *Brongn.*	802–807
Calamites sp.	735–744
Cf. Calamites carinatus *Sternb.*	,,
Asterophyllites charaeformis (*Sternb.*)	783
,, equisetiformis (*Schloth.*)	802–807, 818–82
Calamostachys sp.	818–820
Lepidophyllum sp.	958
Stigmaria ficoides (*Sternb.*)	980
Cordaites sp.	818–820
[1]Carbonicola *cf.* aquilina (*J. de C. Sow.*)	600, 630
[1] ,, sp.	571, 600–607, 631, 744–7
[1] ,, ?	744–747, 901
Crinoidal columnals	1,048, 1,068, 1,171
Fenestellid	1,062
Lingula squamiformis *Phill.*	1,697
,, *cf.* ,,	1,173
,, sp.	1,100
,, ?	977
Orbiculoidea nitida (*Phill.*)	1,428
Productus, *cf.* longispinus *J. Sow.*	1,425
,, sp.	1,425, 1,440
,, ?	1,280, 1,412
Schellwienella sp.	1,425
Cypricardella sp.	1,280
Euphemus urei ? *Flem.*	1,045
Coelacanthus sp.	571
Rhizodopsis sauroides *Will.*	571, 904
,, ,, ?	953–955
,, ?	632
Fish remains, indet.	906

[1] Freshwater shells.

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Mr. Pringle states that 'the marine shells which characterise the rocks passed through between the depths of 1,045 ft. and 1,697 ft., suggest comparison of the beds with the Cefn-y-Fedw Series of Denbighshire.' The latter has been shown in recent years to belong to the Carboniferous Limestone Series. Previously it had been termed 'Millstone Grit.'

The absence in these records of the 'Millstone Grit' of the Whitehaven District, and the extraordinary difference between the Carboniferous Limestone Series in the borings, which is of northern aspect, and that developed in the above district, where by far the greater part is massive limestone, are points of great interest and of economic importance, the significance of which will be better appreciated when the systematic mapping of the area is taken in hand and the various changes followed in detail.

That these changes have taken place before the Boundary Fault is reached from the south is proved by a boring recently sunk by the same Company at Hayborough, about 1 mile east of Ellenborough, in which strata of the Upper Carboniferous Limestone types met with at Bank End and Blue Dial crop out beneath the Glacial beds. Again strata of this lithological character, containing a thin limestone with *Schellwienella*, are exposed in two dingles ½ mile S.E. of Rosegill, and about 3½ miles east of Maryport.

A further point of interest is that the borings tend to prove that there must have been a downthrow (or steep turn-over) south-eastward along, or near the line of, the Boundary Fault, before the date of the Triassic overlap and the later northward downthrow. The supposed Whitehaven Sandstone met with in the above-mentioned driving through the fault, from the Ten Quarters Coal at Ellenborough, may well have been some of the sandstones of the Lower Coal Measures or Upper Limestone Series coloured by Triassic infiltrations.

The Crosby borehole[1] (Fig. 3) appears to have proved a sequence similar to that of the two borings under consideration, but in the absence of fossil evidence it is impossible to say exactly at what depth the Carboniferous Limestone Series was first reached—probably at much shallower depth than 1,046 ft. 9 in. which marks the top of a 33 ft. 3 in. bed of limestone. It appears, therefore, that, in the absence of faults, the base of the Coal Measures of this area strikes more or less parallel to the Boundary Fault and may dip seawards at something like 1,300 ft. per mile—an average dip of from 13° to 14°, which corresponds fairly well with the actual dips observed in the cores. The generally higher dip in the lower series is suggestive of unconformity.

[1] *Ibid.*

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APPENDIX IV.

On a Boring for Coal at Yate, Gloucestershire.

By J. Pringle.

This borehole is situated in a field on the north side of the Bristol road 400 yds. west of Yate Station,[1] at a surface level of 225 ft. above O.D. The operations, which were carried out by Messrs. Vivian's Boring and Exploration Company, Limited, under the management of Mr. Fisher Ray, were begun in August 1918, and were completed in July 1920, after a depth of 2,203 ft. had been reached. The object of the boring was to ascertain the character of the Lower Coal Series present in the eastern limb of the synclinal fold that forms the northern point of the Bristol coalfield. An almost continuous series of cores was obtained by drilling from the surface down to the bottom of the borehole; and through the kindness of Mr. R. M. Dillwyn of Bridgend, Glamorgan, permission was granted to the Geological Survey to examine the rocks thus displayed. A series of rock-samples and fossils was collected, and these are now included in the Survey Collections at Jermyn Street.

The following is an abstract section of the borehole :—

	Thickness. Ft.	in.	Depth. Ft.	in.
Soil and rubble	2	9	2	9
Coal Measures—				
Pennant Series :—				
Grey pennant sandstone with beds of grey sandy shale and a seam of fireclay. Sandstones contain many films of coal, ironstone-nodules, and a few pebbles of coal	853	5	856	2
Soft coal		2	856	4
Strong grey fireclay and grey sandy shale with ironstone	31	5	887	9
Coarse grey conglomerate with many large sub-angular pebbles of quartzite, &c.	4	9	892	6
Bluish-grey and red marls	41	3	933	9
Coarse grey conglomerate, as above	10	9	944	6
Bluish-grey and red marls	6	0	950	6
Grey shaly sandstone	5	3	955	9
Grey conglomerate with many large pebbles	28	7	984	4
Grey pennant sandstone with bands of shale and conglomerate. Joint planes lined with calcite	74	6	1,058	10
Lower Coal Series :—				
Bluish-grey and red marls	8	8	1,067	6
Grey quartzose sandstone	1	9	1,069	3
Bluish-grey sandy shale	19	9	1,089	0
Fine grey sandstone with courses of conglomerate	1	6	1,090	6
Grey and red sandy shale	5	3	1,095	9
Grey shale	35	0	1,130	9

[1] New Series 1-in. Ordnance Map, Sheet 251 (Malmesbury); 6-in. map Gloucestershire 69 S.W.; Old Series 1-in. Geological Map 35, Lat. 51° 32′ 24″, Long. 2° 26′ 12″.

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COAL—*continued.* *Lower Coal Series*—continued.	Thickness. Ft.	in.	Depth. Ft.	in.
Grey sandstone with bands of shale and conglomerate	6	3	1,137	0
Coal		9	1,137	9
Fireclay, sandy shale, and sandstone	20	7	1,158	4
Grey shale	17	0	1,175	4
Coal		2	1,175	6
Fireclay	11	9	1,187	3
Grey shale with a band of grey sandstone, 6 ft. thick, between 1,205 ft. and 1,211 ft. *Marine Band* at 1,227 ft.	68	3	1,255	6
Black shale	3	0	1,258	6
Coal	1	9	1,260	3
Grey fireclay and shale	12	0	1,272	3
Dark-grey and red mottled marl	5	0	1,277	3
Grey shale	18	3	1,295	6
Coal		3	1,295	9
Red and grey mottled marl	53	0	1,348	9
Grey shale	36	3	1,385	0
Coal, soft		3	1,385	3
Grey shale	107	0	1,492	3
Grey sandstone	16	5	1,508	8
Grey shale, numerous plant remains throughout	19	1	1,527	9
Coal, soft	1	6	1,529	3
Coal, soft, and black shale, mixed	1	10	1,531	1
Coal, soft	2	6	1,533	7
Dark shale		10	1,534	5
Dark shale and coal with numerous poorly preserved plants	1	0	1,535	5
Dark grey shale	29	1	1,564	6
Coal	1	0	1,565	6
Grey shale and shaly sandstone. *Marine Band* at 1,610–1,616 ft.	67	3	1,632	9
Red and bluish grey marl	19	3	1,652	0
Dark-grey shale	3	0	1,655	0
Coal		4	1,655	4
Grey shale	37	3	1,692	7
Grey sandstone	6	0	1,698	7
Grey shale	82	9	1,781	4
Grey fireclay	2	0	1,783	4
Grey sandy shale	8	3	1,791	7
Grey sandstone	1	9	1,793	4
Grey sandy shale with numerous plant remains	19	10	1,813	2
Coal	2	0	1,815	2
Dark-grey shale and fireclay	10	6	1,825	8
Grey sandstone	1	10	1,827	6
Grey shale with band of ironstone	27	7	1,855	1
Grey fireclay	1	8	1,856	9
Coal, soft		8	1,857	5
Grey shale with band of ironstone	39	2	1,896	7
Coal, soft	1	2	1,897	9
Dark shale and fireclay	33	7	1,931	4
Grey sandstone		10	1,932	2
Dark-grey shale	3	9	1,935	11
Coal, soft		9	1,936	8
Dark shale	1	6	1,938	2
Coal, soft		8	1,938	10
Dark shale	2	0	1,940	10
Coal, soft		9	1,941	7
Dark shale		9	1,942	4

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Coal—*continued.* *Lower Coal Series*—continued.	Thickness. Ft.	in.	Depth. Ft.	in.
Coal	3	2	1,945	6
Grey shale and sandstone	19	4	1,964	10
Coal	1	4	1,966	2
Grey shale, fireclay, and sandstone	49	5	2,015	7
Coal	4	0	2,019	7
Black shale		5	2,020	0
Coal	1	0	2,021	0
Dark shale	2	4	2,023	4
Fireclay	4	0	2,027	4
Grey shale	13	3	2,040	7
Coal		3	2.040	10
Fireclay, shale, and sandstone	32	0	2,072	10
Grey shale with band of ironstone	38	1	2,110	11
Coal, soft	1	2	2,112	1
Dark-grey shale with band of ironstone	91	3	2,203	4

The dip of the beds, taken at various intervals, appeared to range between 10° and 35°. The rock-sequence displayed in the cores is generally similar to that passed through at Winterbourne,[1] in the western part of the coalfield; but some minor differences were noted. The base of the Pennant Series has been drawn at the depth of 1,058 ft. 10 in., and its position in relation to the highest marine band is nearly the same as in the two corresponding levels at Winterbourne. Beds of coarse conglomerate form a characteristic feature in the lower part of the Pennant Series, although similar but thinner and less coarse pebbly bands occur also in the upper portion of the Lower Coal Series. Many of the pebbles are of large size, one, a grey quartzite from 980 ft., measuring 5 in. in length; and in appearance the conglomerates are identical with those passed through at Winterbourne. Dr. H. H. Thomas, who has examined the specimens, reports that the pebbles are for the most part fine-textured rocks, variously coloured green, grey, and pink, embedded in a matrix which is highly felspathic and quartzose, much of the quartz being opalescent. The chief rock-types are quartzites, rhyolites, and vein-quartz, and, excepting a specimen of a fine-grained brownish sandstone, possibly of Carboniferous age, the whole assemblage, which is seemingly identical with that found at Winterbourne, again suggests derivation from rocks of Pre-Cambrian formations. No pebbles of the older Palæozoic sediments were recognised. The majority of the pebbles are subangular, and their marked increase in size, as compared with the constituents of the Winterbourne conglomerates, suggests that the source of the material lay somewhere east or north-east of the coalfield, and may indicate the presence of a buried ridge of Pre-Cambrian rocks in that direction.

In the Lower Coal Series beds of sandstone resembling Pennant rock are present, but they are subordinate to the argillaceous sediments, which are chiefly of the mudstone type.

[1] T. C. Cantrill and B. Smith, 'On a Boring for Coal at Winterbourne, Gloucestershire,' 'Summary of Progress for 1918' (*Mem. Geol. Surv.*) 1919, pp. 53-57.

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The lower shales are remarkably slicken-sided. Most of the coals are soft and thin, and are frequently interbedded with shale. A seam of good quality, 4 ft. thick, was passed through between the depths of 2,015 ft. 7 in. and 2,019 ft. 7 in. It is separated from a lower coal, 1 ft. thick, by 5 in. of black shale. Two marine bands were detected in the measures. At 1,227 ft. fragments of *Lingula* were found in association with numerous shells of *Orbiculoidea nitida* (Phill.); and between the depths of 1,610 and 1,616 ft. the shales yielded several finely ribbed specimens of *Productus*. These marine bands appear to represent similar horizons passed through at the depths of 1,090 and 1,488–1,494 ft. in the Winterbourne boring. Some of the shales were found to be crowded with plant-remains, but considerable thicknesses yielded no fossils. The identification of the plants by Dr. R. Kidston F.R.S. is as follows :—

	Depth in Feet.
Alloiopteris (Corynepteris?) coralloides (*Gutbier*)	1,909
Linopteris *cf.* obliqua *Bunbury*	1,171
Lonchopteris bricei *Brongn.*	1,974
Mariopteris sp.	1,171
Neuropteris tenuifolia (*Schloth.*)	1,525, 1,711
,, sp.	1,525, 1,697, 1,711, 1,719
Pecopteris (Dactylotheca?) sp.	1,697
,, sp.	1,562
Sphenopteris *cf.* artemisiæfolioides *Crepin*	1,525
,, obtusiloba *Brongn.*	1,711
,, sp.	1804–1810
Calamites cisti *Brongn.*	,,
,, sp.	,,
Annularia microphylla *Sauveur*	1909
Asterophyllites equisetiformis *Schloth.*	1,525
Palæostachya sp.	1,973
Lepidophyllum lanceolatum *L. & H.*	1,711
Sigillaria mammillaris *Brongn.*	1,510
Cordaites principalis (*Germar*)	1,525
,, sp.	1,711, 1,804, 1810

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APPENDIX V.

TOTAL QUANTITY OF TIN, COPPER, AND OTHER MINERALS PRODUCED IN DEVONSHIRE, PARTICULARLY WITH REGARD TO THE AMOUNTS RAISED FROM EACH PARISH.[1]

By Donald A. MacAlister, A.R.S.M.

Many of the mines of Devon, like a still greater number in Cornwall, have long since been abandoned, and the topographical positions of such as are mentioned in records have only been determined after laborious examination of hundreds of old mine-plans preserved in local estate offices and institutions; in the Office of Woods and Forests, the Home Office, the Duchy Office and the Geological Survey, as well as a number in private ownership. It was only by this means that the recorded output of minerals could be classified according to parishes.

The tabulation of the production according to parishes presents a shorter and more rational account of the economic value of a mineral tract of country than could be obtained by a detailed list of outputs from the individual mines.

The totals from each parish during the periods are computed from the separate returns of the mines in them, as derived from the various sources mentioned on p. 274 of the *Geology of Falmouth and Truro*. As it was not until 1882 that continuous and reliable returns were published, it is likely that the details of the Tables fall short of the true amounts raised in the periods covered, and the reservations stated in the *Summary of Progress* referred to, as well as those in the memoir last cited (p. 274) must be borne in mind when considering the value of any mineral area. It will be recognised that although the records of early production are fragmentary there is enough evidence of different kinds to show that several of the ores have been worked from time to time for centuries past, and that it is impossible to embody such information in the Tables.

Mr. Lewis[2] states that the statistics of the production of tin from Cornwall and Devon in the late 12th century are not plentiful and relate mostly to Devonshire. From his perusal of the pipe-rolls Mr. Lewis was able to draw up tables of annual returns in which, however, there are many lacunæ amounting in the aggregate to several hundred years. The value of any attempt to estimate the quantities produced in the missing

[1] For the output from the parishes of Cornwall *see* 'Summary of Progress of the Geological Survey of Great Britain for 1906' (*Mem. Geol. Surv.*), Appendix II, 1907, p. 132.

[2] '*The Stannaries*', 1908.

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years would, at best, be doubtful, as even if the existing records were reliable, we should still have to assess the effect on production due to wars and social conditions, in addition to the usual uncertain elements in mining and trade. It may be noted, however, that from the 13th century to the middle of the 18th century many tens of thousands of tons of metallic tin were produced from the West Country.

With regard to copper it is quite certain that the ore was raised concurrently with tin-ore from the earliest historical times; but Lysons states[1] that in 1811 only seven mines in Devon were yielding copper, and that in that year the production was as follows:—Wheal Friendship, 110 tons; Wheal Crebor, 1,308 tons; Crowndale, 863 tons; East Crowndale, 913 tons; Wheal Hockworthy, 10 tons.

The early official statistics are far from satisfactory, and although care has been taken in the Tables which follow to present a true account in accordance with available data, the amounts here given should be regarded merely as useful guides to the relative importance of the mineral areas.

We may briefly recall the fact that the available records contain many lacunæ and probably mistakes,[2] so that although we know the sources we do not know the precise extent of the errors likely to be present. The observations contained in Appendix II. of the *Summary of Progress* already referred to apply with equal force to the mineral output of Devon and need not be repeated.

The periods covered by the Tables are necessarily restricted to the 19th and 20th century, as earlier records are scarce and discontinuous.

The principal production of lead ore was in the forties and fifties of the 19th century, though it continued to be raised until the eighties; the silver was obtained mainly from the lead. We recall, however, the historical fact that the silver-lead mines of Devonshire were worked at least as far back as the 13th century.[3] Manganese was actively mined in the seventies, but we note that considerable quantities of this ore, as well as iron ore, were raised in the 18th as well as the early part of the 19th century.[4] Zinc ore was raised mainly in the fifties and sixties. The output of tin ore, as expressed in the Tables, is limited to that since 1852; of copper ore since 1821; of lead ore since 1845; of silver since 1852, and of miscellaneous minerals since 1853.

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[1] *Mag. Britt.*, Devon, p. cclxxxiii.

[2] Such as those due to confusion between the natural and dressed ores and the metal, as well as to false returns.

[3] *See* 'Geology of Cornwall, Devon and West Somerset' (*Mem. Geol. Surv.*), pp. 611, 612.

[4] *Op. cit.*, pp. 610, 617.

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TABLE I.—*Output of Tin and Copper from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Tin Ore produced from* 1852 *to* 1913; *and the Copper Ore from* 1821 *to* 1913.

Parish.	Black Tin.	Copper Ore.	Copper.[1]	Parish.	Black Tin.	Copper Ore.	Copper.
	Tons	Tons.	Tons.		Tons	Tons.	Tons.
Ashburton -	804	421	17	Molland - -	—	1,180	75
Beer Ferris -	10	205	13	North Bovey -	1,314	—	—
Belstone -	1	4,036[2]	375	North Molton	—	4,515	638
Bovey Tracey	—	2,300	86	Okehampton -	—	2,656	186
Buckfastleigh -	—	29,680	1,965	Peter Tavy, *see* Mary Tavy.	—	—	—
Buckland Monachorum	12	24,250	1,400	Plympton St. Mary - -	1,300	240	12
Chagford - -	60	—	—	South Tawton	—	6,285	344
Dartington -	56	—	—	Sydenham Damerel -	—	80	5
Holne - -	6	—	—	Tavistock -	300	933,210	59,682[3]
Ilsington -	91	—	—	Walkhampton	220	280	21
Lamerton -	61	22,600	1,285	Whitchurch -	515	20,630	1,538
Lydford - -	295	—	—	Miscellaneous -	10	1,150	80
Manaton -	203	—	—				
Mary Tavy -	408	43,250	4,015				
Meavy - -	400	—	—				

[1] Obtained from the copper ore mentioned in the previous column.
[2] Over 1,000 tons contained about 9 per cent. copper.
[3] In addition, about 90 tons of 'precipitated copper' yielding 70 per cent. of the metal.

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TABLE II.—*Output of Minerals, other than Tin and Copper, from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Lead Ore raised since* 1845; *the Silver since* 1852; *and the Miscellaneous Minerals since* 1853; *to* 1913.

Parish.	Lead Ore.	Lead.[1]	Silver.[2]	Pyrites (Iron and Arsenical).	Arsenic[3] Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Ashburton - -	—	—	—	720	903	22,060	The pyrites mostly arsenical. The iron oxides are 'Brown Hæmatite,' ochre and umber. Of this, 12,820 tons of ochre and umber were returned from 'Roborough' and 'Devon and Cornwall' Mines, and some from 'S. Devon Mine,' which also returned 690 tons 'spathic iron.'
Beer Ferris - -	25,670	16,324	534,010	20	—	—	The pyrites non-arsenical. Also 3,240 tons of fluor-spar.
Belstone - - -	—	—	—	102	21	—	Of the pyrites, 72 tons were arsenical.
Bovey Tracey - -	—	—	—	—	—	2,878	Of which 1,060 tons 'micaceous' iron ore, 123 tons ochre and 667 tons 'Brown Hæmatite.'
Bratton Fleming -	—	—	—	—	—	20	Red Hæmatite. Also 10 tons of manganese ore, part of which came from Sherwell Parish, *q.v.*
Brentor - - -	—	—	—	—	—	155	Ochre. Also 3,610 tons of manganese ore.
Bridford - - -	—	—	—	—	—	—	21,250 (?) tons of barytes.
Brixham - - -	—	—	—	—	—	196,311	Mainly 'Brown Hæmatite,' containing up to 50 per cent. iron. Some micaceous and some sold as ochre and 'Wolston's iron paint.'

[1] From the lead ore. [2] From the lead. [3] In addition to the arsenical pyrites.

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TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Buckfastleigh - -	—	—	—	350	—	—	Of which a proportion was arsenical.
Buckland Monachorum	—	—	—	7,575	1,715	—	Pyrites mainly arsenical.
Budeaux - - -	62	36	1,436	—	—	—	
Challacombe - -	—	—	—	—	—	50	'Brown Hæmatite.'
Chevelstone - -	—	—	—	—	—	300	'Brown Hæmatite.'
Christow - - -	26,550	17,506	367,230	—	—	689	Of the iron oxides, 48 tons were ochre and umber; 240 tons 'Brown Hæmatite,' and 182 tons 'spathic iron ore' (*see* Lustleigh). In addition, 180 tons of fluor-spar and 1,635 tons of zinc-ore.
Combe Martin - -	860	545	812	—	—	1,340	Of the iron ore, 450 tons were 'Brown Hæmatite,' and 890 tons 'umber.' In addition, 1,590 tons of 'spathic iron ore.'
Coryton - - -	—	—	—	—	—	—	*See* Milton Abbot.
Georgeham - -	—	—	—	—	—	780	'Brown Hæmatite.'
Harford - - -	—	—	—	—	—	900	'Brown Hæmatite.'
Hennock - - -	800	550	1,190	—	—	1,935	The oxide of iron was 'micaceous iron ore.' In addition, 1,200 tons of manganese ore.
Ilsington - - -	93	60	80	—	—	46,512	Of the iron oxides, 21,928 were magnetite, 16,209 'Brown Hæmatite,' 5,717 mixed 'Brown Hæmatite' and micaceous iron ore ('shining ore'), containing up to 57·5 per cent. of iron, 708 tons of ochre, 340 tons of umber, 220 tons of so-called 'Wolston's iron paint.' In addition, 1,474 tons of zinc-ore.

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Kingsbridge	—	—	—	—	—	54	'Brown Hæmatite.'
Lamerton	62	39	2,915	1,410	1,011	—	Of the pyrites, 350 tons were arsenical. In addition, 602 tons of zinc ore and 77 tons of manganese ore.
Lew Trenchard	—	—	—	—	—	—	156 tons of Manganese ore. *See also* Marystow and Milton Abbot.
Lustleigh	—	—	—	—	—	1,580	Part of this from Bovey Tracey and Shuttamoor in Christow; 342 tons were 'Brown Hæmatite,' and the rest 'shining ore.'
Lydford	12	8	—	—	—	—	
Marlborough	—	—	—	—	—	100	
Marystow	—	—	—	—	—	—	1,820 tons of manganese ore, but this includes some from Milton Abbot, Lew Trenchard, Cardwell and St. Stephen.
Mary Tavy	2,000	1,176	9,150	17,875	7,685	—	Of the pyrites, 10,508 were arsenical. In addition, 160 tons of zinc ore. 'Scheelite,' and 1 ton of Wolfram from Wheal Friendship.
Milton Abbot	—	—	—	—	—	—	49,890 tons of manganese ore, but part of this came from Lifton, Sydenham Damerel, Lew Trenchard and Coryton. *See also* Marystow.
Molland	—	—	—	—	—	28,560	'Brown Hæmatite.'
North Bovey	—	—	—	—	—	25	Specular iron or 'shining ore.'
North Molton	25	9	—	150	—	17,081	Of the iron oxides, 14,181 tons were 'Red Oxide,' and 2,900 'Brown Hæmatite.' In addition, 9,625 tons of 'spathose iron' and 86 tons of manganese ore. The pyrites was non-arsenical.
Newton Abbot	—	—	—	—	—	—	40 tons of manganese ore.
Newton St. Cyres	—	—	—	—	—	—	1,401 tons of manganese ore.
Peter Tavy	—	—	—	—	—	—	*See* Mary Tavy.
Plympton St. Mary	771	367	12,050	911	270	—	Of the pyrites, 210 tons were arsenical. In addition, 8 tons of zinc ore.
Rattery	—	—	—	—	—	4,400	'Brown Hæmatite.'

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TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
St. Stephen	—	—	—	—	—	—	Manganese, *see* Marystow.
Shaugh Prior	—	—	—	—	—	5,317	Mainly 'Brown Hæmatite,' 250 tons were 'Red Hæmatite.'
Sherwell	—	—	—	—	—	535	'Brown Hæmatite.' In addition, 55 tons manganese ore, *see* Bratton Fleming.
South Molton	80	60	64	—	—	—	
Stoke Gabriel	—	—	—	—	—	4,790	'Brown Hæmatite.'
Sydenham Damerel	100	69	947	—	—	—	140 tons Zinc ore. For Manganese, *see* Milton Abbot.
Tavistock	1,300	931	13,144	72,001	86,460	4,290	Of the pyrites, 50,393 tons were arsenical and 3,823 mixed 'crude arsenic and arsenical pyrites.' Oxides of iron as ochre and umber. In addition, 30 tons of wolfram and 60 tons of fluor-spar.
Ugborough	285	171	2,688	—	—	2,432	Of the iron oxide, 2,233 tons were 'Brown Hæmatite' and 199 tons ochre.
Walkhampton	—	—	—	—	2	—	
Whitchurch	12	7	—	152	—	—	Of the pyrites, 33 tons arsenical.
Wolborough	—	—	—	—	—	1,240	'Brown Hæmatite.'
Yealmpton	—	—	—	—	—	250	'Brown Hæmatite.'
Miscellaneous (unclassified)	740	565	2,575	—	—	—	160 tons of Manganese ore from 'Rostidyon' and 'Fullabrook.' 640 tons of iron ore from 'Furgam Mill' (? Brixham). The lead-ore is from 'Park,' 'South Maex,' 'True Blue,' 'Thomas United' and 'New Devon Consols.'

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